BRITISH WELDING JOURNAL

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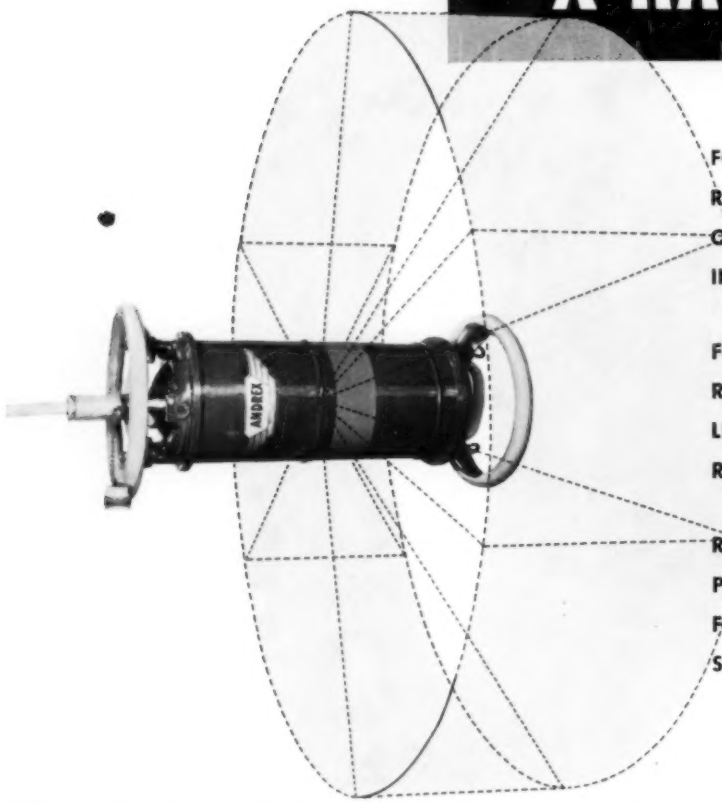
ANDREX

360° PORTABLE X-RAY UNIT



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RADIOGRAPHIC INSPECTION
OF CIRCUMFERENTIAL WELDS
IN ONE EXPOSURE

FORWARD THROW 360°
RADIAL BEAM MAKES
LIGHT WORK OF TOUGH
RADIOGRAPHIC JOBS

RADIATION BAND WIDTH 30°
PROVIDES EXPOSURE OF
FULL SEAM WITH WIDTH TO
SPARE ON EITHER SIDE

Ideal for inside-out one shot circumferential radiography of tank head welds and girth welds in any cylindrical object

ANDREX 160 KVP/360° PORTABLE X-RAY UNIT IS

LIGHT WEIGHT — one man can easily carry its 72 lb tube head.

COMPACT — can enter a 9" diameter opening.

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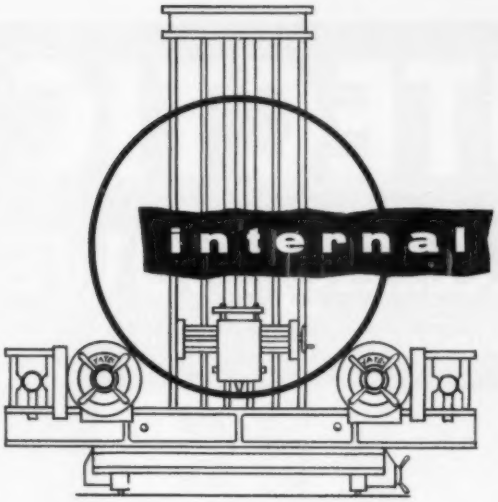
Sole U.K. Distributors: B. I. X. Ltd., Hanover House, 73 High Holborn, London WC 1.

Inside front cover



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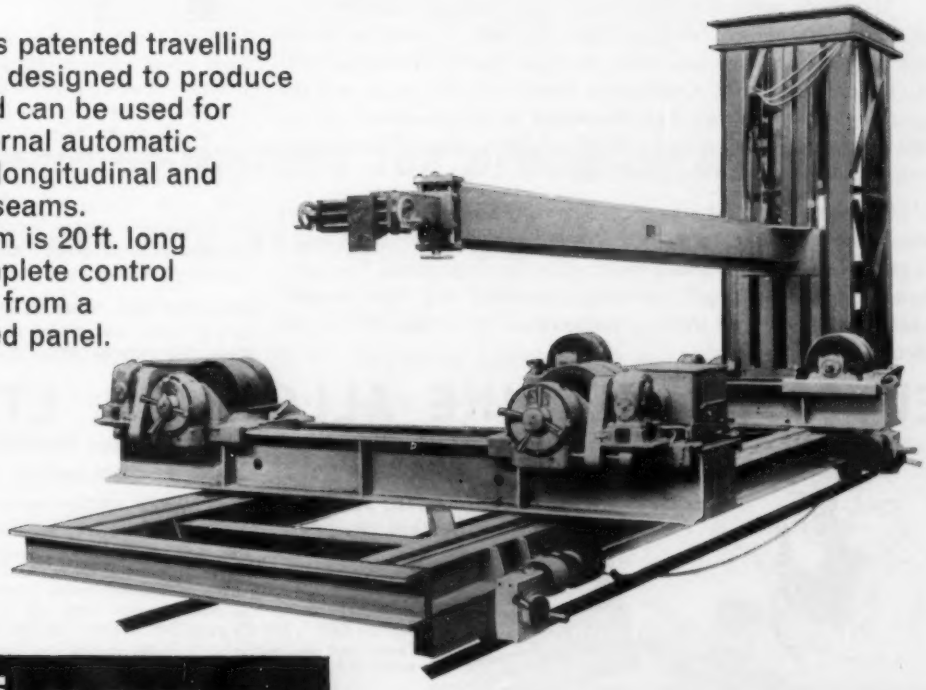
This 15-ton Yates patented travelling rotator has been designed to produce Class 1 work and can be used for internal and external automatic welding of both longitudinal and circumferential seams.
The elevating arm is 20 ft. long and there is complete control of all operations from a pedestal-mounted panel.



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BP 108

ORIGINAL
Low Temperature
EUTECTIC
WELDING ALLOYS

Head Office and Factory Feltham · Middx

EUTECTIC Welding News

PUBLISHED BY EUTECTIC WELDING ALLOYS COMPANY LIMITED, FELTHAM, MDDX.

HISTORY OF "EUTECTIC LOW TEMPERATURE WELDING ALLOYS"

Surface alloying at low heat was first discovered by "Eutectic" in 1904 - used today in over 100,000 plants. "Eutectic" is the originator and sole manufacturer of "Eutectic Low Temperature Welding Alloys" for bonding metals at low heat, minimizing distortion, warping and stress.

"LOW HEAT INPUT" INCREASES PRODUCTION JOINING 500%

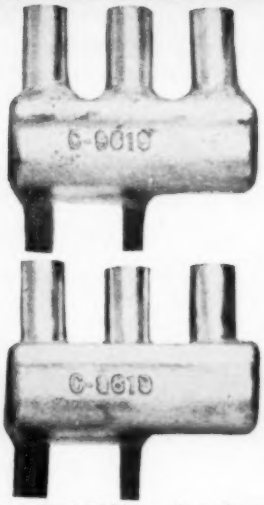
Excessive and costly rejects in fusion-joining three copper pipes to a machined bronze casting led a manufacturer of heating equipment to investigate the savings possible with modern fabricating techniques.

A high melting silicon bronze rod was used, with three fusion welds, to obtain suitable density, strength and corrosion resistance. Top welders did the work to overcome the problems of distortion, warping and keeping the pipes parallel.

The manufacturer was satisfied (Photo A) until Eutectic's Technical Representative recommended EutecRod 1801, a thin flowing high silver alloy, used together with Eutector Flux 1801.

The three tubes were pre-fluxed with Eutector Flux 1801 and set up simultaneously. A large torch tip with a broad flame was used to heat the work and when the flux liquified, EutecRod 1801 was fed into the joint. Continuous motion of the torch, and the superior capillarity of the alloy, prevented localised overheating and distortion, allowing uniform fillets to form around the entire circumference of each tube (Photo B).

Due to the extreme ease of application of EutecRod 1801, perfect joints were produced. Filler alloy was reduced by 56 grammes to the 6.2 grammes of EutecRod 1801 required by the three joints. The joints showed superior strength, corrosion resistance and "eye appeal". EutecRod 1801 reduced working temperature by at least 300°C, and rejects were diminished.



A.

B.

EutecRod 1801, a thin flowing high silver content alloy with medium plastic range, is one of the lowest melting but strongest of all silver bearing alloys, with an ultimate tensile strength of 40 tons sq. in. Joints are ductile, and leakproof, offering exceptionally good corrosion resistance and electrical conducting properties.

EutecRod 1801: Available in sizes $\frac{1}{16}$", $\frac{3}{32}$" dia., and strips to order from .020 x $\frac{3}{32}$" to .003 x 1".

EUTECTIC 'LOW TEMPERATURE WELDING ALLOYS' FORMULATED FOR 'LOW HEAT INPUT' BONDING OF ALL METALS INCREASE SAVINGS BY SALVAGE AND REPAIR, SOLVE PRODUCTION PROBLEMS

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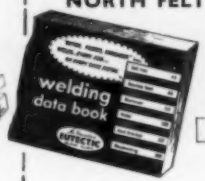

A completely revised 100 page Welding Data Book for 1959. Thousands of welding users keep this handy book within easy reach — every page is crammed with practical, valuable information — so much so that many call it the welder's "Bible". And it's yours free... from "EUTECTIC".

☐ *Please send me further details of EutecRod 1801.* ☐ *Please send my free copy of Eutectic's Welding Data Book.*

☐ *Please send your Technical Representative for free consultation/demonstration.*

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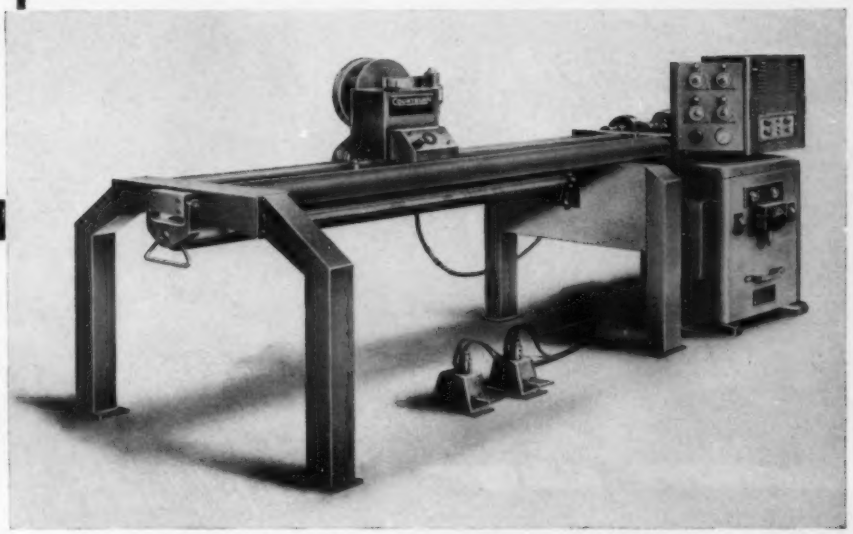

A complete equipment for precision welding of titanium and stainless steel thin sheets

The Courtburn LONGITUDINAL BUTT WELDING MACHINE is the first machine of its kind in Great Britain designed specifically for precision welding of titanium and stainless steel thin sheets. This machine will speedily weld flat sheets of $\frac{1}{64}$″ to $\frac{9}{64}$″ thickness and will accommodate cylinders from 7″ to 42″ diameter and up to 6 ft. in length. Incorporated in this equipment is the latest ARGONARC AUTOMATIC ARC LENGTH CONTROL UNIT which will ensure faultless continuous welds on any metal for which the argon arc process is suited.

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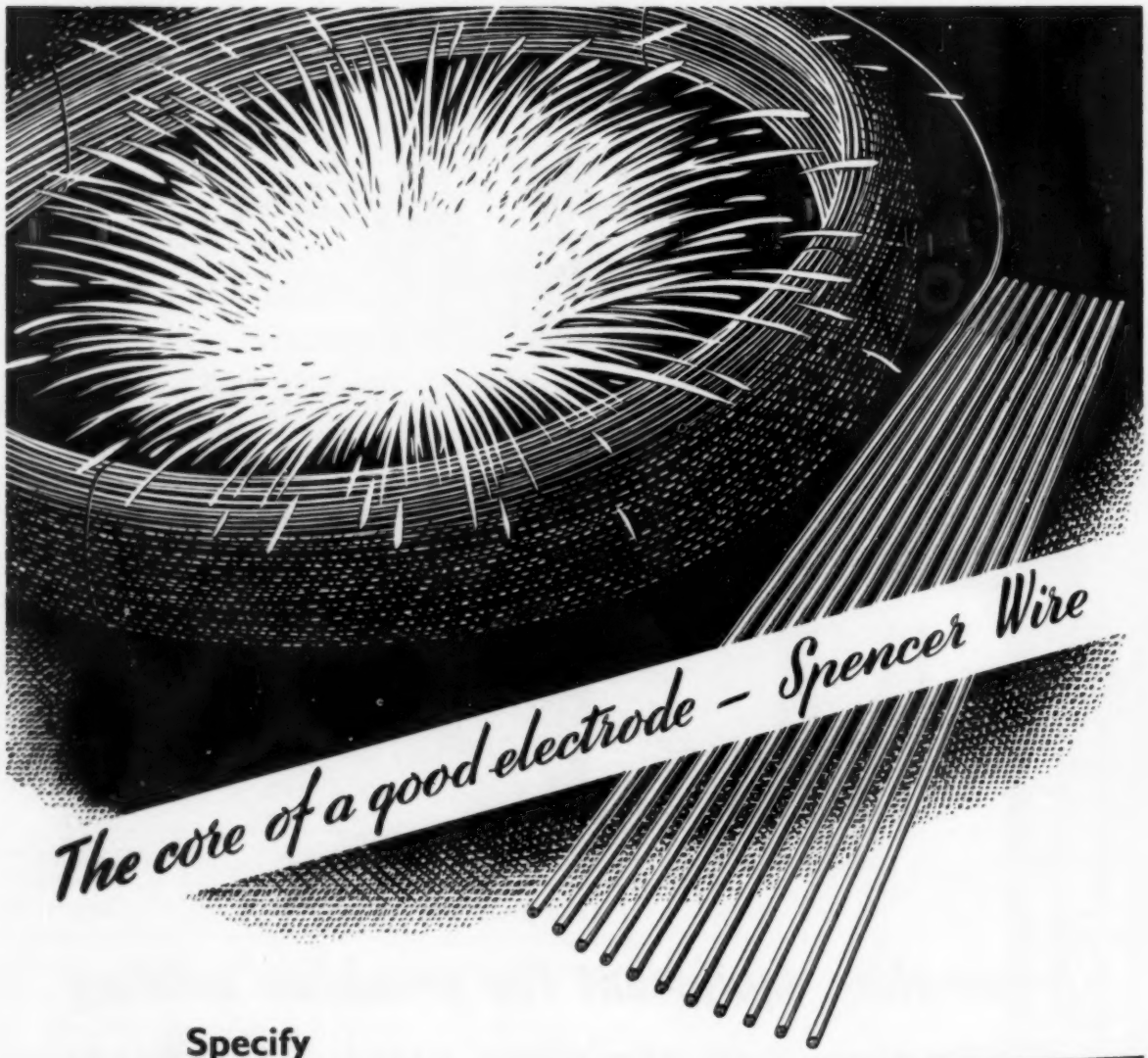

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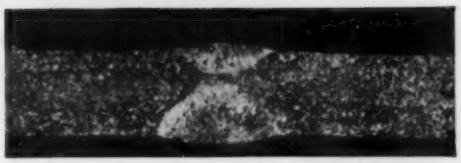
DaW 1258 W

WELDING OF NON-FERROUS METALS

Metal-arc welding of an 'Everdur' pressure vessel.

This macrograph illustrates the quality of weld easily achieved in 'Everdur' A alloy, using the argon arc process and I.C.I. filler rod.



TECHNICAL NOTES: NO. 4:

Welding 'Everdur'

'Everdur' is the trade name for a range of copper-silicon-manganese alloys made by I.C.I. Metals Division. These alloys are widely used in chemical plant and other applications calling for a material stronger than copper but equally corrosion resistant.

Of all copper alloys, 'Everdur' is the easiest to fusion weld, and autogenous welds of high quality can be made by the gas, carbon arc, tungsten arc and inert-gas metal arc welding processes.

Imperial Chemical Industries Limited, Metals Division, produces large tonnages of non-ferrous metals and alloys for brazed and welded assemblies, and a wide range of rods and wires for brazing and welding.

The Company's Research Department has for many years carried out development work on the joining of metals. The experience gained is freely available to all interested in this subject.

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.I.

M.14

ICI METALS DIVISION

DECEMBER, 1958

Hand-operated Flash-butt Welding Machines

FROM THE METROVICK RANGE

Here is a selection from the comprehensive range of standard Metrovick hand-operated flash-butt welding machines, which are designed to cover a wide variety of sections for both jobbing and production work. Ease of operation, rapid clamping of work, and simple adjustments are outstanding features.

Please write for details of any machine in which you are interested.

HAND-OPERATED FLASH-BUTT WELDING MACHINES

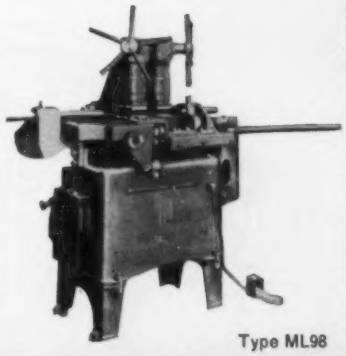
Type	kVA Rating		Maximum Upset Force (tons)	Normal Range in M.S.	
	Thermal	Max.		Thin Section (sq. in.)	Compact Section (dia.)
MC109	4	55	½	0.05 to 0.3	⅛ in. to ½ in.
MC75	10	100	1	0.1 to 0.6	5/16 in. to ⅝ in.
ML75	10	100	1	0.2 to 0.6	⅜ in. to 1 in.
HFB45/2	30	90	2	0.25 to 1.5	½ in. to 1⅝ in.
ML98	40	80	2½	0.25 to 1.5	½ in. to 1¾ in.
MW92	90	135	5	1 to 4	¾ in. to 2½ in.

METROPOLITAN-VICKERS
ELECTRICAL CO. LTD · TRAFFORD PARK · MANCHESTER, 17

An A.E.I. Company

LEADING WELDING PROGRESS

Type MC109 (bench mounting)

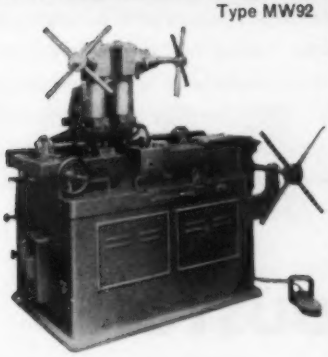


Type ML98

Type MC75

ML98 tipping M.S. shanks with H.S.S cutting ends.
Photograph by courtesy of Messrs. F. M. Parkin & Co. Ltd., Sheffield.

Type MW92



Type HFB45/2

Type ML75

L/W805

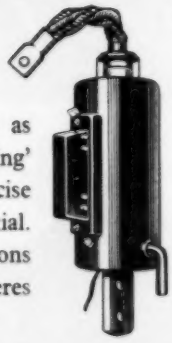
For ZETA

... for Industry

Zeta, with inset showing BTH 'clamping' ignitron.

B T-H

IGNITRONS



IN ZETA, BTH Ignitrons are employed as electronic switches for 'discharge' and 'clamping' duties, and perform vital tasks where precise timing and complete reliability are essential. Specially developed for the project, these ignitrons carry peak currents in excess of 20,000 amperes in the 25,000-volt power circuit.

BTH Ignitrons for industrial applications, such as resistance welding control and power rectification, are manufactured to the same exacting standards. The Company offers the widest range of ignitrons in the United Kingdom and all these are interchangeable with corresponding American types.

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Progress Way, Croydon, Surrey.
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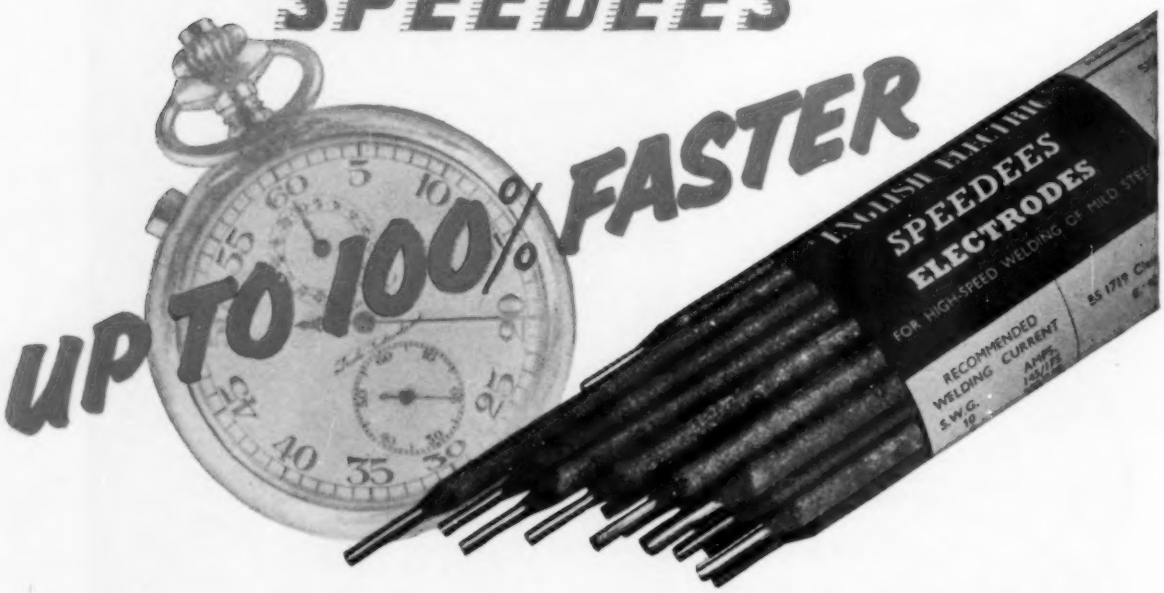
The electrodes for

FASTER WELDING

are

SPEEDEES



SPEEDEES welding electrodes have been developed by 'ENGLISH ELECTRIC' specifically for easier, faster and more economical welding of mild steel. They produce well-shaped fillets with an extremely smooth finish. An iron powder is incorporated in the electrode coating, and in practice SPEEDEES have proved to increase production rates by anything up to 100% as compared with conventional electrodes of the same gauge.

Send for publication WA/132 and literature covering the range of standard 'ENGLISH ELECTRIC' welding electrodes.

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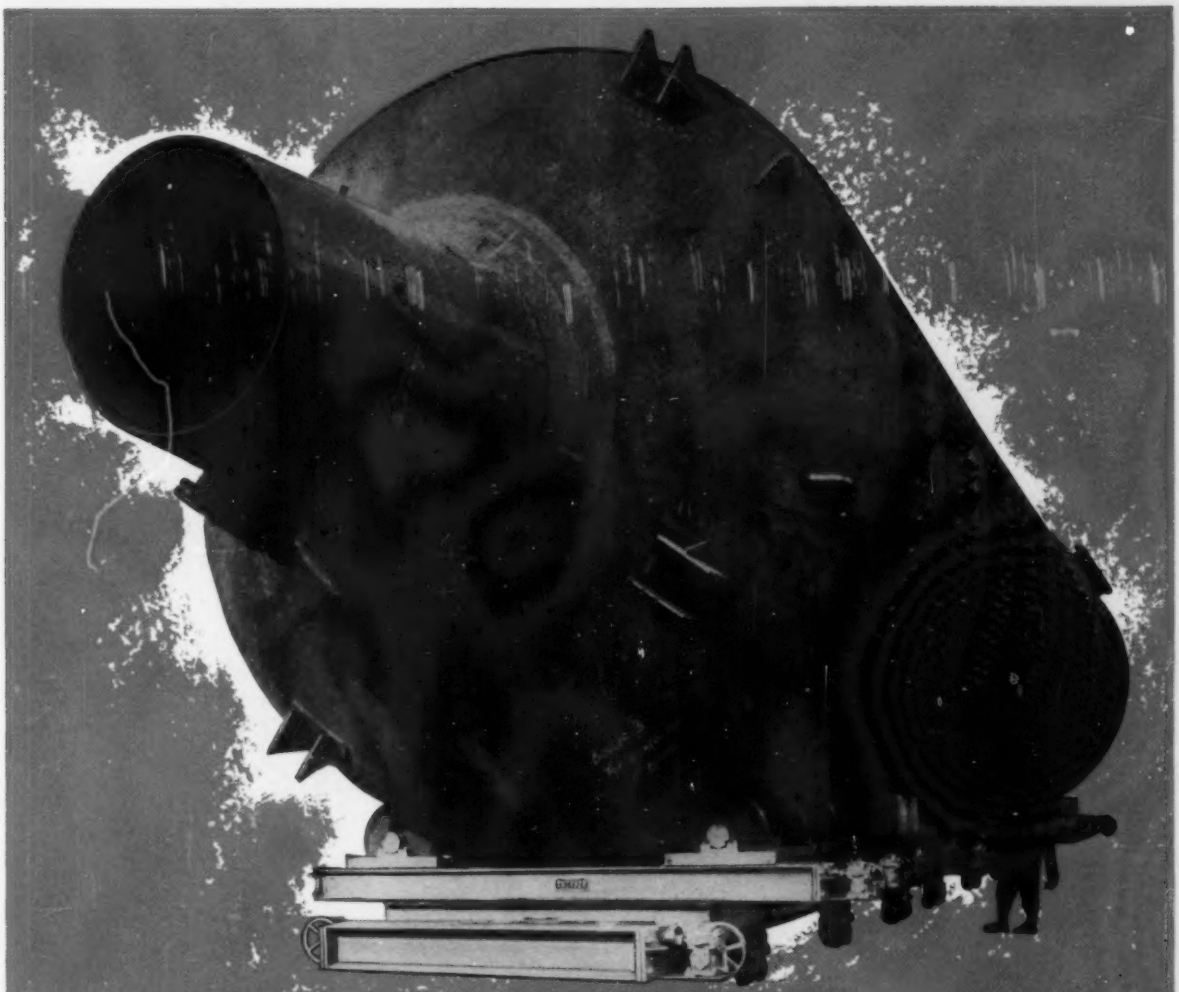

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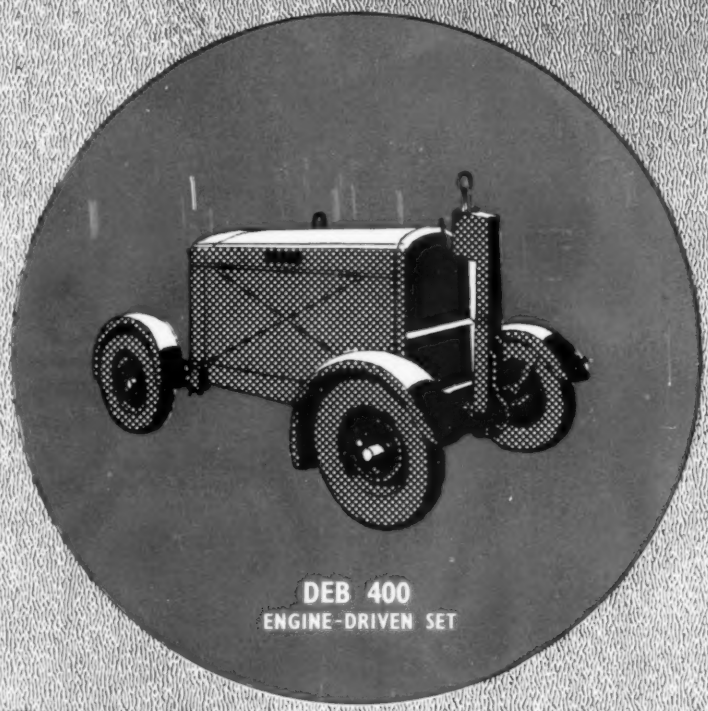
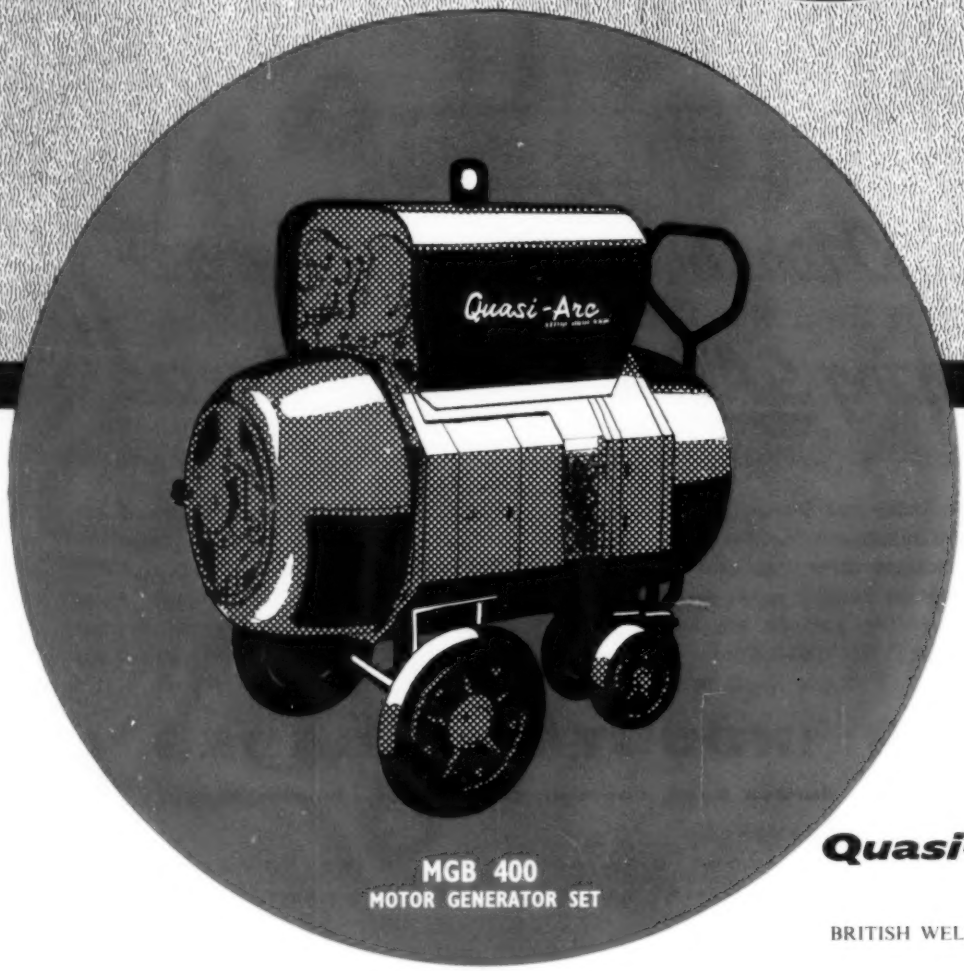
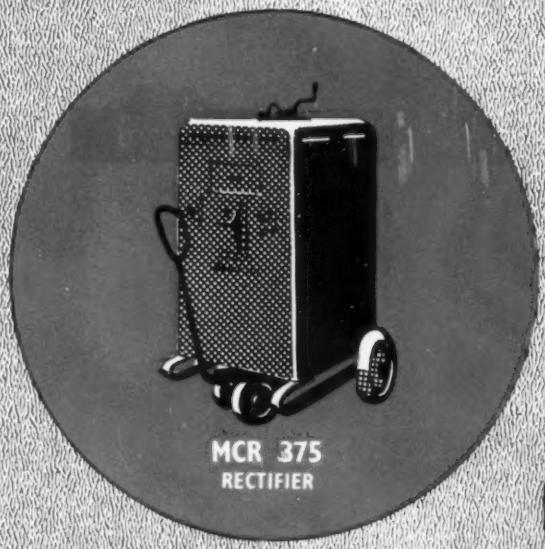


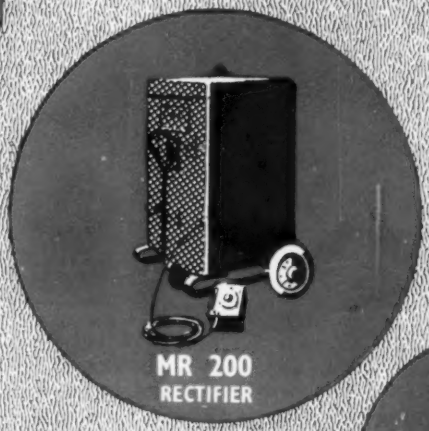
DEB 400
ENGINE-DRIVEN SET



MGB 400
MOTOR GENERATOR SET

Quasi-Arc





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High efficiency and exceptionally stable arc.

Wide, infinitely variable current ranges, with selection by simple, safe and optional remote controls.

Low running costs because of small no-load current.

Current range up to 600 amps. for manual welding (1200 amps. for automatic welding).

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Strong construction for reliability in all conditions.

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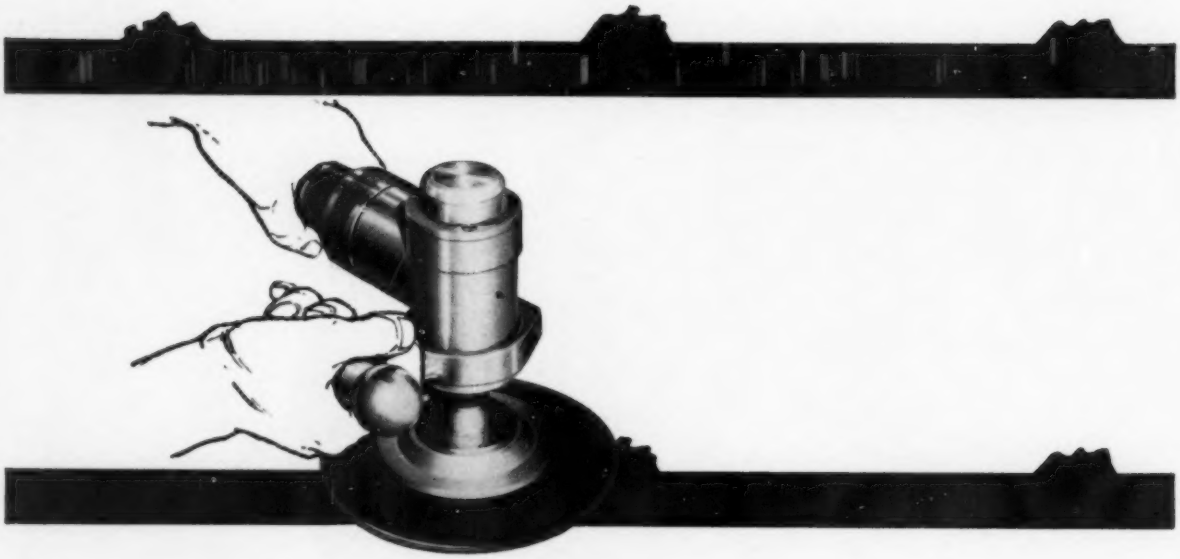
world leaders in arc welding Quasi-Arc Limited, Bilston, Staffordshire

Taking the rough with the smooth...



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CARBOFLEX is a registered trade mark of the Carborundum Company Limited.

CARBOFLEX DEPRESSED-CENTRE WHEELS

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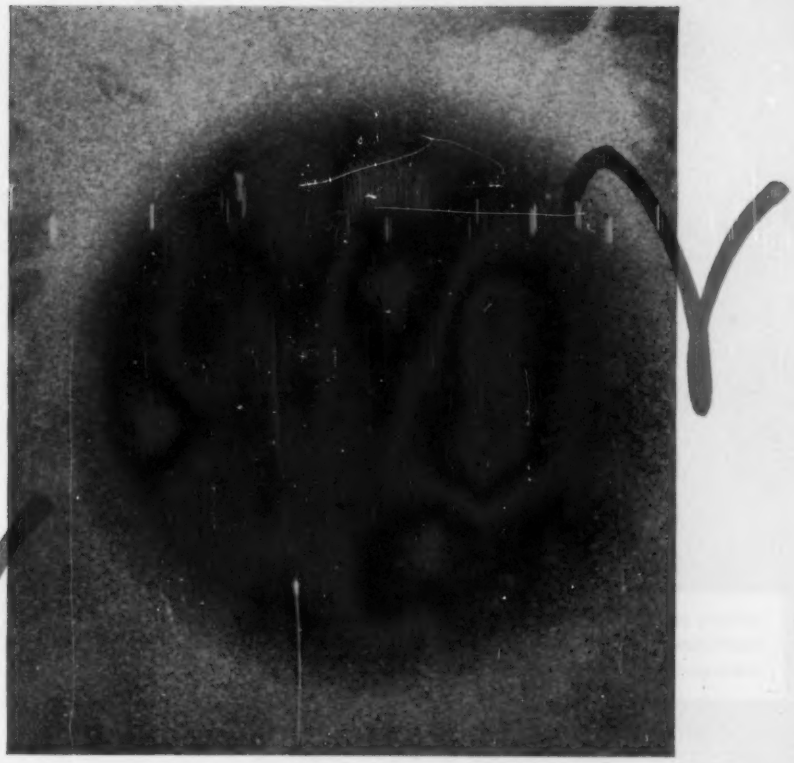

2mm + 2mm light alloy spot weld, magnified 7 times

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This new addition to the range of Ilford Industrial X-Ray films will give greatly improved radiographs of steel welds and light-metal castings. For examinations at up to 200 kVp it is twice as fast as Industrial C and with gamma-ray techniques it is as much as three times as fast. Because of its higher contrast and finer grain, it gives better definition than is possible with Industrial B. The inherent high contrast of Ilford CX makes this new film extremely useful for radiography with 1- and 2-million volt apparatus as well as with gamma rays. Ilford CX Industrial X-Ray film may be used with or without lead screens. The recommended developer is Ilford PQX-1.

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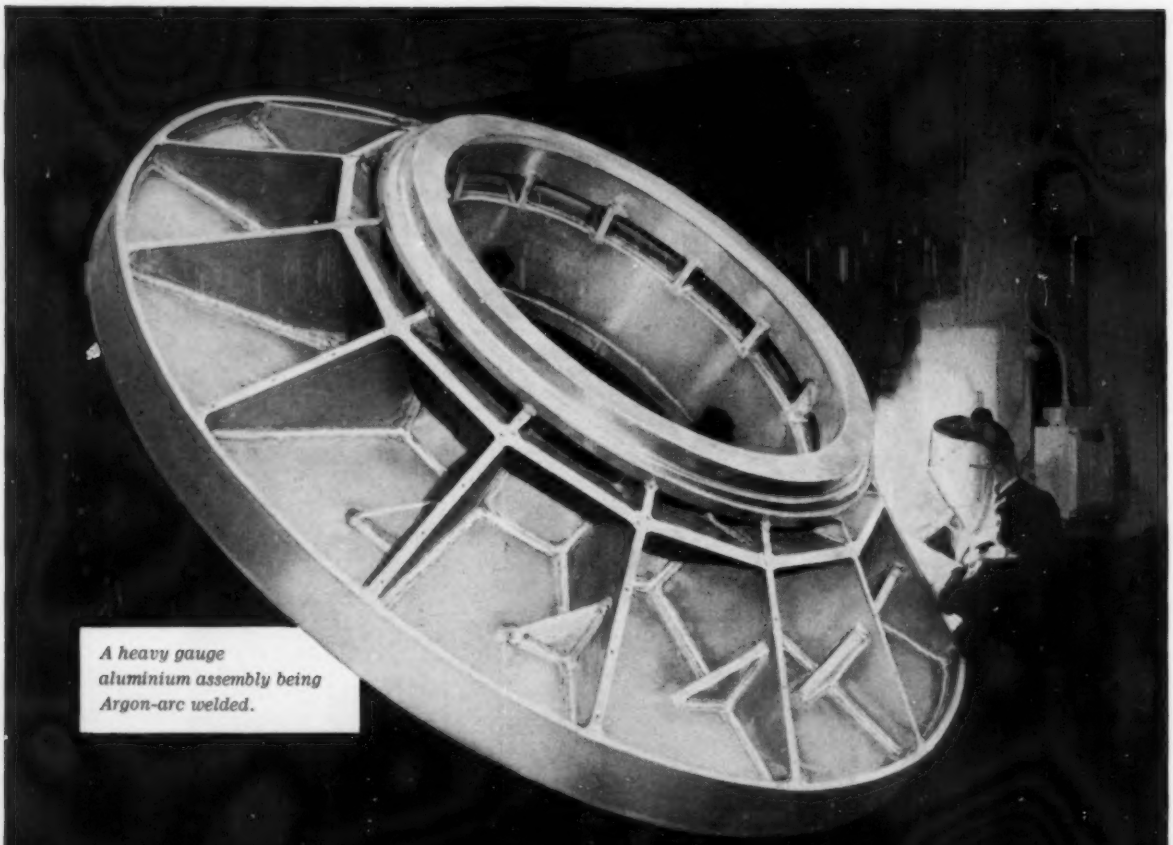

A heavy gauge aluminium assembly being Argon-arc welded.

Enthusiasm for perfection

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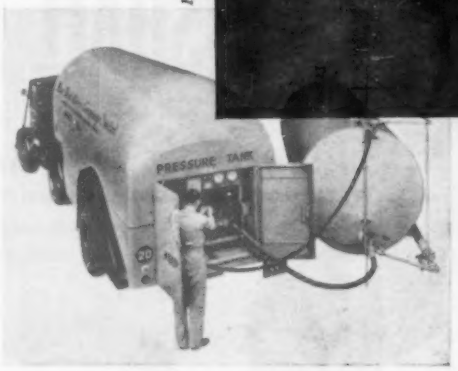
ICI

MAR 248

Photograph illustrating the FUSARC/CO_2 process by courtesy of Quasi-Arc Limited



The use of low pressure CO_2 gas as an inert shield in the welding of steels is increasing. CO_2 is not only cheap — it enables high quality welds to be made in the shortest time.

Where automatic welding machines have been specially modified to use this technique, the simplicity, ease of slag removal and high speed of welding have been found most impressive. On one differential housing, for example, welding time has been reduced from 105 to 23 seconds.

CO_2 ARC WELDING

DCL

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Bulk liquid can be pumped direct from the Company's road tankers into customers' static tanks (of capacity $1\frac{1}{2}$ or 6 tons) without interrupting the flow of CO_2 to the operators.

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Chemical Division—Carbon Dioxide Department

Devonshire House, Piccadilly W.1

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Depots and Branches throughout the U.K.

Illustrated above is a Pressure Tank

STEEL FABRICATIONS BY THOS. MARSHALL

AND SON LTD.

THOS. MARSHALL & SON LTD
WELLINGTON BRIDGE, LEEDS, 12
Telephone: 32186 (5 lines) Grams: 'Cisterns' Leeds 12

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A new PURHYPO Silver Recovery Unit

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Just fix the rectifier unit on a wall conveniently near the fixing tank, and suspend the electrode assembly in your tank. If fixing space is too small, the electrodes can be fitted after working hours, or in a separate reserve tank to which exhausted hypo is transferred for regeneration.

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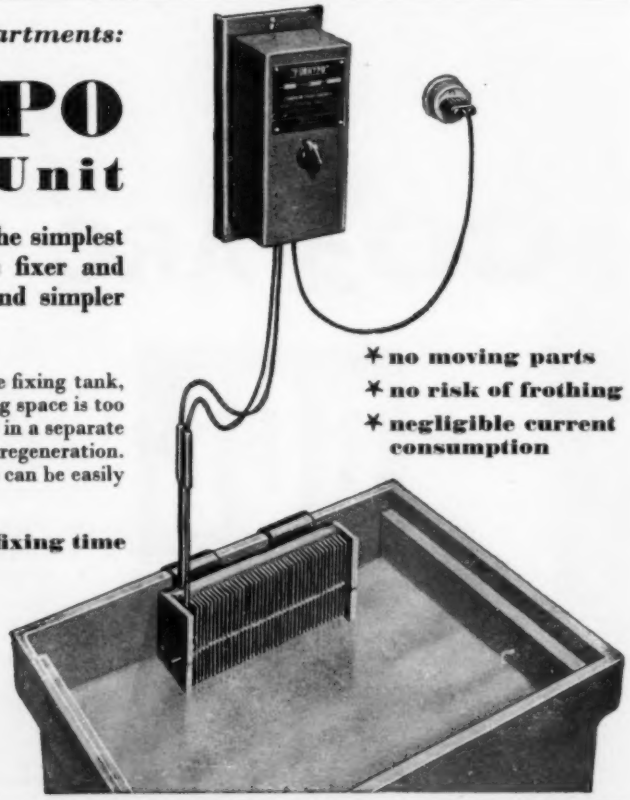

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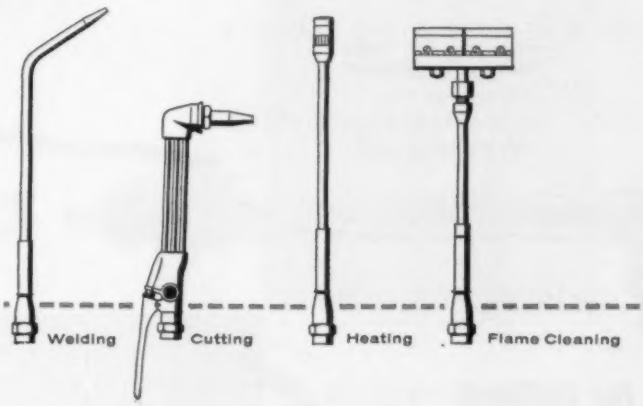

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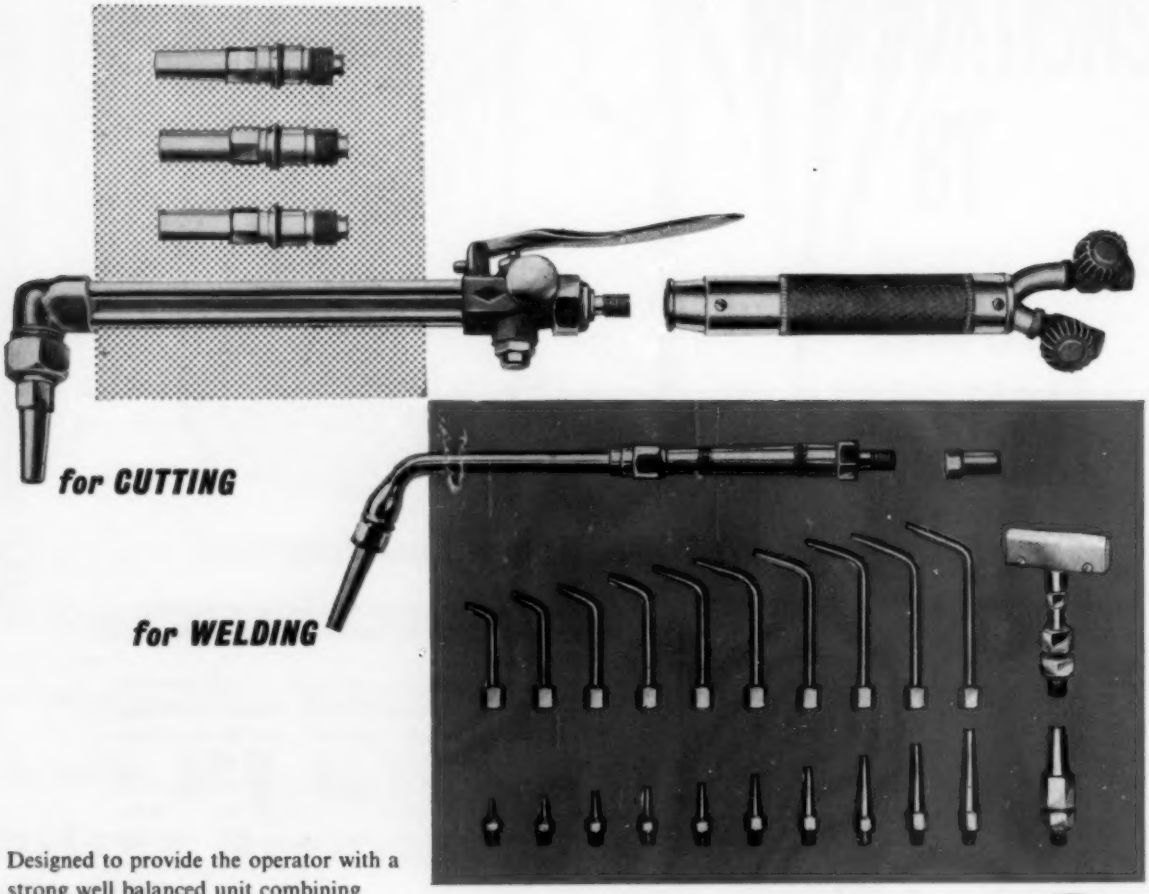

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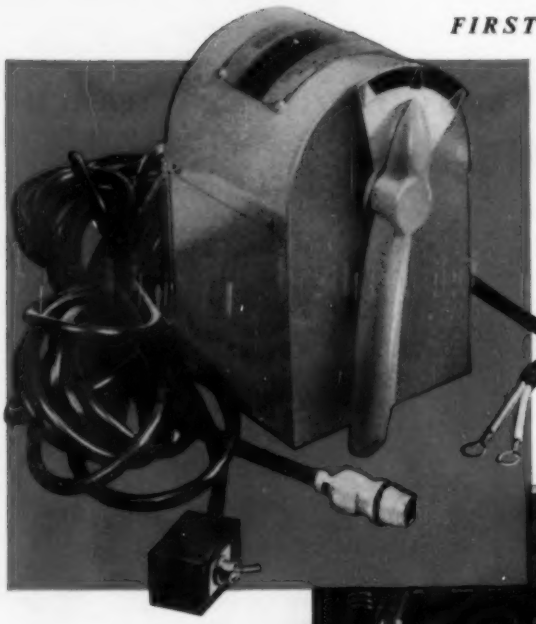

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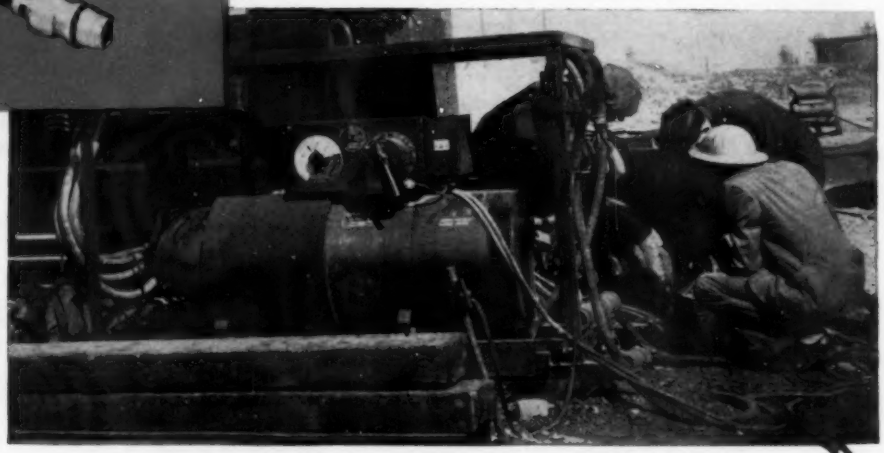

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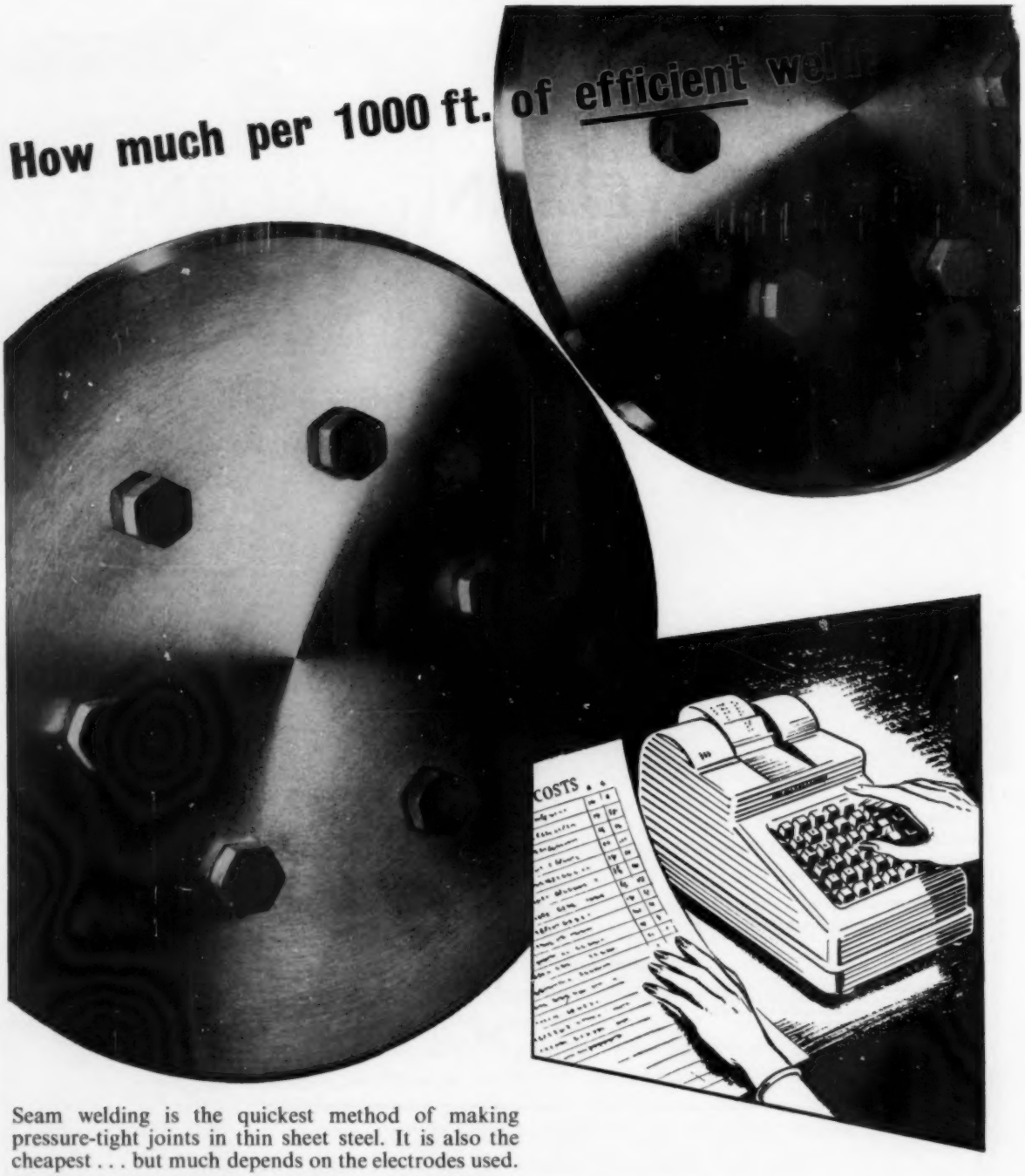

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Welding

TECHNOLOGY

Presidential Address

WELDING PROCESSES: SOME THOUGHTS ON THE PRESENT STAGE OF DEVELOPMENT

By

J. Strong, M.A.

I should like, gentlemen, in this address, to discuss broadly certain aspects of the current state of development of some of the welding processes, particularly arc welding and the varied processes and equipment which apply in that field.

We have now arrived, I suggest, at a most interesting point, perhaps a turning point from which may emerge a pattern that will apply for many years to come.

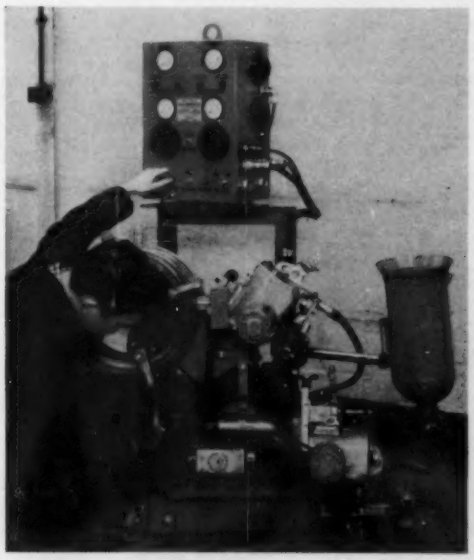
There have, of course, been other turning points; for instance, at the introduction of oxy-acetylene welding in the last century, and the development of flux-covered-electrode welding around 1910. There have also been periods of relative quiescence in the development field. But certainly very substantial and far-reaching developments have been occurring over more recent years with the great advance of automatic welding methods and the introduction of the principle of inert and other gas shielding.

As a result of the ingenuity of scientists and engineers, we have reached a stage of great diversification in welding equipment. Is this trend to continue or is there to be a rationalization? We are all considering these things at this time, not least the suppliers of the multitudinous types of equipment and materials now required for the great range of processes which they have helped to promote. A few words from this quarter may perhaps be of interest at this stage.

Oxy-acetylene welding still exists in its several forms. This amazingly successful and tenacious series of techniques has its place—a broad one; it is still going strong, and it has years of success ahead of it yet. But the tendency is to use the readily attained very high temperature of the electric arc where conditions permit, and this source of heat, applied under the influence of inert gas, is even entering the field of accurate high-speed cutting as well.

Arc welding in Britain came into prominence, as we all know, with the advent of manual flux-covered electrodes. This system held sway for many years; materials, metallurgy, application, techniques, and cost improving all the time. It still forms the bulk and the backbone of arc welding applications.

Naturally there were those who thought about means of mechanizing this efficient but intermittent system. There were difficulties, and some of them persist today. Nonetheless, pioneers produced two long-established systems of so-called fully automatic welding, using a flux-covered electrode in coil form or welding with a bare wire under a burden of powdered

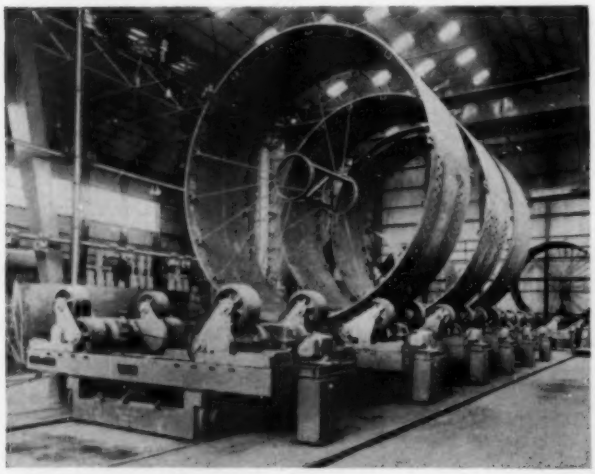


Self-propelled submerged-arc machine fitted with two welding heads and control panels for multi-power welding

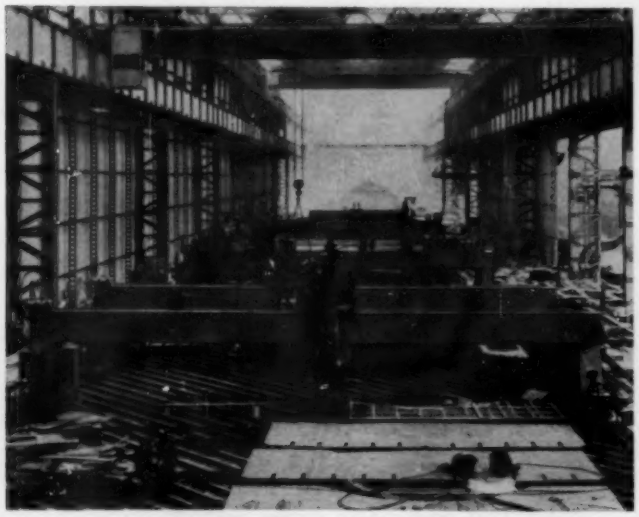
This Address was presented at the Autumn General Meeting of the Institute on 6th November 1958.

flux. These two important processes moved ahead side by side, the former being used for medium-current welding, for outdoor work, or where it was of value to see the arc in operation. The latter was used also for very light work, and even more so for very heavy welding. The finish of the weld was exceptionally good, and for some shop work it was preferred because the arc was hidden, or submerged. These processes, with variations, continue to flourish today.

During this time, and especially in recent years, it came to be recognized that, to give automatic welding a proper chance to show what it could do, one must —as in other automatic processes—think as hard about appropriate handling gear as about the welding equipment itself. Hence the development of jigs and manipulators, which can serve any automatic process equally well. At first, there were plain roller beds to turn and traverse the work, light gantries, and cantilevers—leading to a vast range of specialized equipment which, as the use of automatic welding expands, tends to become more and more 'standard', leaving the designers to reach out ever further, with their special designs, to make automatic welding daily more practicable for applications which hitherto were considered to be out of its reach.



Roller bed units for use in conjunction with high-lift booms carrying submerged-arc multi-power welding heads



60-ft span welding gantries carrying submerged-arc welding heads for fillet welding bulkhead stiffeners and butt welding panel sections

Meantime, the search for an ideal semi-automatic system has continued; but the designer still has a long way to go with this admittedly difficult problem. Semi-automatic welding is, or should be, a flexible system. It should call for less capital equipment than does fully automatic welding, and it is particularly suited to varied work. The potential supplier knows that the ideal semi-automatic system, when it is developed, will find waiting for it an immediate and ever-expanding demand.

The problems, however, are quite considerable. The essential limitation on heat and current; the demand for positional welding ability; convenience, lightness and portability with robustness; simplicity —all these factors and more serve to make the final development of semi-automatic welding a problem of considerable depth.

However, progress has been made in quite a wide

Self-contained semi-automatic inert-gas welding equipment, including rectifier and portable wire feed and control unit

range of applications, particularly through the introduction of inert-gas shielded metal-arc processes with their fine bare wire electrode in coil, which followed the introduction of the very successful manual tungsten-arc, and now automatic, processes employing an arc from a non-consumable electrode with or without the addition of a bare filler rod or wire in coil. But here the limitations so far lie in the fact that to facilitate the semi-automatic aspect a flux may not readily be employed, which restricts the field of use and still leaves us without a truly universal semi-automatic system of arc welding.

Yet it is interesting to consider how at this stage of arc-welding development a definite impetus was given by those particularly concerned with gas welding, through their recognition that certain gas-forming ingredients in an electrode flux might with advantage be omitted when a shielding gas could be admitted neat, so to speak, at an appropriate cost.

Still more recent developments in the form of tubular electrodes with flux in the core providing virtually a flux-filled bare wire, and a wire to which magnetic powder adheres, inert or semi-inert gas being used as an additional shielding agent, are also on their way, but we still await that ideal semi-automatic process whose introduction will be a real prize to the ingenious inventor who finally solves the very considerable collection of practical problems involved.

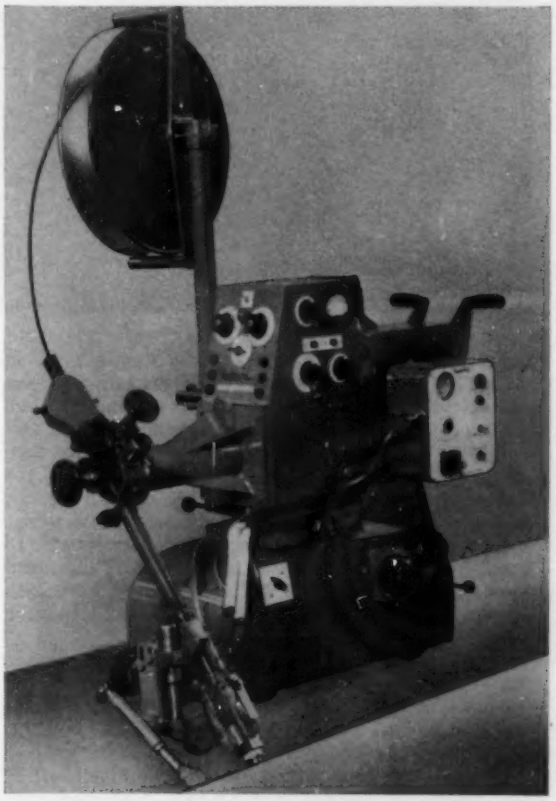
One thus sees now a very wide range of arc welding processes available to industry, some having been evolved quite independently of each other. Even ignoring individual variations, manual covered-electrode welding includes: automatic and semi-automatic covered electrode and submerged-arc welding, the former nowadays with or without an independent shielding gas; gas shielded tungsten-arc welding, manual and automatic; gas shielded welding, semi-automatic and automatic, using bare wire with the possible addition of emissive agents now being investigated by the scientists; a flux-filled tubular electrode, or a bare wire to which magnetic flux adheres, both with the addition of a shielding gas; the inert-gas shielded tungsten-arc or consumable bare wire electrode spotwelding processes; the automatic covered electrode process using a submerged-arc flux, and so on. A tremendous array that makes one ponder. Must the multiplication continue if welding is to expand, or can an amalgamation of some or all of these processes be achieved? Is no further rationalization possible?

These aspects of welding development have been given much attention in recent years, and I believe the time is coming when there can and will be a very considerable simplification. This, I know, has been said before but usually by the enthusiast who has seen in a new process the culmination of that ideal of universality with simplicity that we are all looking for.

Some of those who started flux-covered electrode welding thought it would put an end to oxy-acetylene welding. Some, when inert-gas shielded welding with bare wires appeared, believed that it would rapidly supersede fluxed electrode welding in most of its forms. But instead, the multiplication—for good reason, we know—has gone on, and all the processes are flourishing today.

I would just like to take a few more minutes of your time to point to what I believe will be the future course of development in this very wide field. I am thinking of arc welding now in its various forms.

I believe there will be a steady tendency to combine or to loop up various processes to form something that is better than any one of the constituents. Examples of what has already been done lie in the use of CO_2 shielding with an automatic flux-covered electrode;

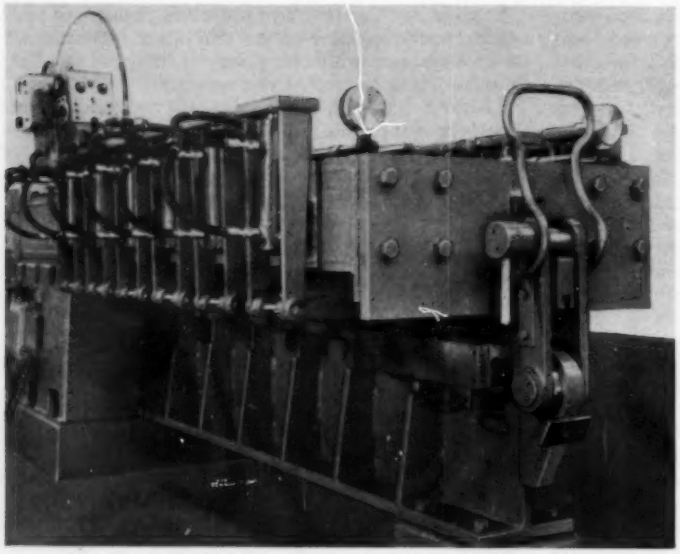


Fusarc/CO_2 self-propelled welding machine for lap welding of tank bottoms

the use of gas shielding with magnetic flux; and the automatic flux-covered electrode working under a fused submerged-arc flux. This tendency, entirely scientific and logical as it can be, needs to be pressed home. Perhaps, in time, instead of a dozen processes, each possessing individual advantages over the others, we shall have three or four.

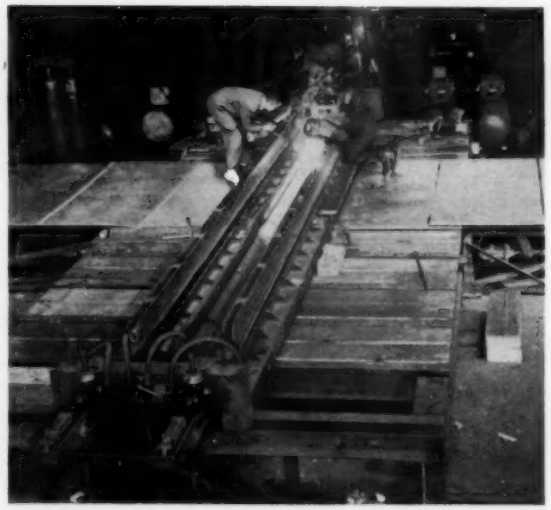
This will at once permit further rationalization of automatic welding head designs and a greater standardization of electrical power-supply equipment. One can see this coming now in the automatic and semi-automatic welding heads that will cater for four or more of the present processes, and a similar trend is appearing in the various forms of electric power supply.

Then out at the end, and applicable already to most automatic processes, comes the handling gear. The jigs and manipulators, which I have already mentioned,



Backing bar press incorporating hydraulically operated clamping jaws for welding ½ in. thick plate up to 5 ft long

Fully automatic argon arc welding machine and clamping jig used on railway hopper car side sheets



are being steadily rationalized and standardized in design while covering a wider field than ever before.

I consider too that in automatic welding we shall see more and more of the complete installation and complete machine. I have sometimes likened the provision of a welding head on its own to the supply of the engine of a car. Before it is of use one must fit a body, transmission, and wheels. It seems to me that if equipment becomes, as I think it may, more complicated in itself so as to have a more universal and simplified application, so the need for a complete machine to operate to a guaranteed performance will become increasingly apparent.

Perhaps it would be wise now to set out to provide the greatest rewards to those who carry forward the intelligent rationalization of processes, welding equipment, materials, the electric power-supply equipment, jigs and manipulators; especially those who achieve the most effective and universal, yet compact, set of processes and equipment: also to those who are able to provide an ideal semi-automatic process whose introduction would at once relieve the struggles of those designers of fully automatic equipment and manipulators to make their designs reach down to pick up the one-off—which belongs to manual and semi-automatic welding—as well as the multiple job.

Of course, some ingenious scientist may, in time, find a totally new way of imparting welding heat, perhaps through the direct application of nuclear energy, but in this address I have tried to keep my feet on the ground and to suggest that we have now, no doubt temporarily, reached a stage where consolidation is perhaps the most important factor to be borne in mind.

This is a subject which, I admit, is so full of interest to some of us that thoughts far outrun the scope of an address such as this. Perhaps, though, the expression of these thoughts will serve to show how keenly the supplier of equipment and materials, helped as he is by daily contact with all the ingenious and enthusiastic people who back him up and lead him on, how keenly the supplier is aware of the need for more and better semi-automatic welding and for a greater rationalization of processes and equipment to follow the many constructive and promising individual developments which have taken place in this great field of welding in recent years. I believe it is the correct line of thought to follow and I commend it to all who are concerned with the development of processes, equipment and materials in this sphere. To the users I commend it too, because no simplification or standardization has yet been achieved in any sphere without sacrificing some relative inessentials in the interest of progress as a whole.

B.W.R.A. REPORT

Projection Welding of Mild Steel

By G. A. Phipps, A.M.Inst.W.

SYNOPSIS

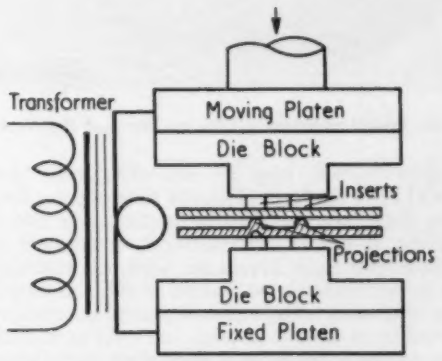
THIS report is a revision of part of Publication T.30, the British Welding Research Association's code of practice on the projection welding of mild steel sheet, and extends its scope as a result of recent research by the Association. Amendments and additions have also been made in the light of observations from Commission III of the International Institute of Welding. Other sections of this code of practice will be revised later.

PROJECTION welding is a method of resistance welding in which current flow and heating during welding are localized by the form of the parts being welded rather than by the electrodes in contact with the work. This is usually accomplished by a projection on one or both of the workpieces, as shown in Fig. 1, formed by pressing sheet metal, by forging or machining from solid pieces, or by using special shears or punches on the edge of strip. The advantages of projection welding compared with spot welding are:

(*a*) Ease of obtaining satisfactory heat balance for welding difficult combinations of dissimilar thickness
(*b*) More uniform results in many applications, particularly where welds are required at close pitch
(*c*) Several welds can be made simultaneously
(*d*) Longer electrode life and lower electrode maintenance
(*e*) The process lends itself to the use of assembly fixtures
(*f*) Finished appearance is often improved
(*g*) Parts may be projection welded that could not otherwise be welded.

PROJECTION WELDING MACHINES

Projection welding machines are basically the same as those used for spot welding, except that they are generally more massive in all respects. The current capacity must be generally greater, and the mechanical rigidity must be increased, for the currents and loads involved are considerably higher than in spot welding because several welds are made simultaneously. A projection welding machine usually has a shorter throat and therefore a lower secondary loss than a spot welder, so that a given size of transformer will give a greater secondary current. The short throat is also advantageous in withstanding the heavy applied loads. A typical machine is shown in Fig. 2. The moving head must be rigid laterally but it must be light and have free movement in the direction of the applied loads so that it will follow the collapse of the projection and maintain the load on the weld as it is formed. It is desirable that the downward speed of the head should be controllable so as to avoid excessive impact, which may lead to premature cold collapse of the projections. Current control in projection welding is generally more critical than in spot welding, especially as the number of projections being welded at one time is increased. It is essential, therefore, that some accurate timing device is used to control the duration of the current, and also that the magnitude of current should be controllable in fairly small stages. This may be achieved by providing a number of tappings on the primary side of the welding transformer, sometimes supplemented by phase-shift heat control. Special machines, such as the 3-phase frequency changer type, or single-phase types with slope control of current, may be advantageous in some applications. With slope control, the current increases gradually at the beginning of welding, thus limiting the rate of projection collapse so that load may be maintained during the formation of the weld.



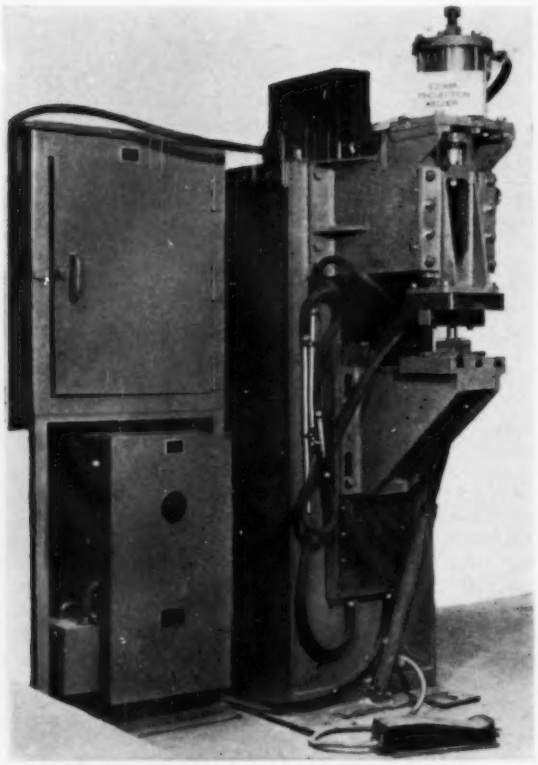
1—Diagram showing principles of projection welding

Electrodes

The electrodes used are normally large relative to the size of weld, and therefore comparatively little forging of the weld takes place after the projection has collapsed, and little or no surface marking is produced. The material for electrodes should be one of the specially developed copper alloys, having a conductivity from 50 to 85% I.A.C.S.* with corresponding hardnesses between 240 and 110 D.P.N., which will give reasonable electrode life. If a particularly long life is required the use of a more expensive material, such as

Report B3/2A/58 of the British Welding Research Association, issued to members in June 1958.
Mr. Phipps is a Research Officer with the Association.

* International Annealed Copper Standard, which is a specific resistance of 1·7241 $\mu\Omega$/cm at 20°C.



2—Typical projection welding machine used at B.W.R.A

tungsten-copper, may be desirable. Such material should be in the form of inserts generally not less than ¼ in. thick, and attached by brazing to a substantial backing of one of the previously mentioned alloys. If tungsten-copper inserts are used it is essential that the components to be welded should be clean. The area of contact between the insert and the components should be at least four times the weld area, and contact over this area must be good since, if the contact is poor, local hot spots will occur, with consequent burning and disintegration of the insert at these points. Electrodes must always be efficiently water-cooled, and must be accurately aligned under load in the welding machine. If this is not done, poor quality welds may be produced and electrode life will be reduced considerably. The surface finish of the electrodes on initial installation can also have an important effect on the electrode life, and it is desirable that as smooth a surface as possible should be obtained, for example, by surface grinding. The electrodes may be incorporated in jigs or fixtures for locating parts in the machine, but care must be taken that any such locating devices do not form a current path alternative to the projections. The use of magnetic material for jigs and fixtures must be avoided, for such material, if in the machine throat, will become heated from the eddy currents induced every time a weld is made, and will also reduce the secondary current of the machine by increasing the inductive losses. A typical electrode assembly for triple projections is shown in Fig. 3.

Table I

Some sheet steels in common use for projection welding

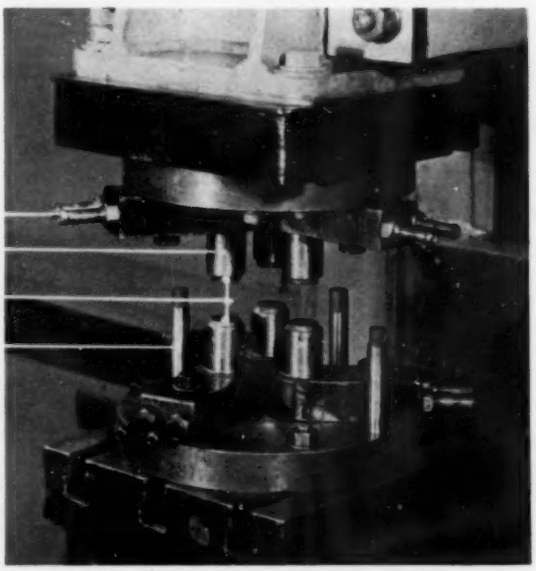
	Composition (max.), %					
Specification	*C*	*Si*	*Mn*	*S*	*P*	*Others*
S.84	0·12	0·20	0·50	0·05	0·05	Ni 0·30*
DTD 330	0·08	0·20	0·40	0·05	0·05	—
En. 2A	0·12	—	0·50	0·05	0·05	—
En. 2A/1	0·10	—	0·50	0·04	0·04	—

* If the nickel content is greater than 0·1%, trouble may be experienced.

ONE, TWO OR THREE PROJECTIONS IN LOW-CARBON STEEL SHEET

Materials

The projection welding of mild steel sheet is mainly carried out using material with a carbon content not



3—Electrode assembly for welding triple projections

Table II

Projection sizes

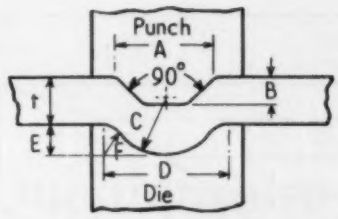
Thickness Range in.	s.w.g.	Projection Dimensions, in. A	B	C	D	E & F	Projection No.
0·021–0·027	24	0·103	0·040	0·050	0·118	0·028	0·6
0·028–0·037	22 / 20	0·118	0·045	0·056	0·132	0·031	0·8
0·038–0·052	18	0·136	0·050	0·063	0·150	0·035	1·0
0·053–0·071	16	0·160	0·056	0·071	0·170	0·039	1·5
0·072–0·099	14	0·185	0·063	0·080	0·190	0·044	2·0
0·100–0·134	12 / 10	0·212	0·071	0·090	0·212	0·049	3·0
0·52 –0·70	0·6	2·58	1·00	1·25	3·00	0·71	0·6
0·71 –0·96	0·8	3·00	1·12	1·40	3·35	0·80	0·8
0·97 –1·29	1·0 / 1·2	3·45	1·25	1·60	3·75	0·90	1·0
1·30 –1·82	1·5 / 1·75	4·00	1·40	1·80	4·25	1·00	1·5
1·83 –2·46	2·0	4·62	1·60	2·00	4·75	1·12	2·0
2·47 –3·39	2·5 / 3·2	5·30	1·80	2·24	5·30	1·25	3·0

exceeding 0·1%. If the amount is greater than this, particularly if it is associated with high percentages of manganese (greater than 0·6%) and nickel, chromium, molybdenum, etc. (any one greater than 0·1%), difficulty may be experienced owing to the formation of extremely hard and brittle welds. Generally, the thicker the material being welded, the higher is the carbon content that can be tolerated. Examples of steels which may be used successfully for projection welding are given in Table I. Welds from a single application of current in higher carbon materials (more than 0·1%C), may be satisfactory, but a post-heat treatment may be necessary to temper the weld and heat-affected zone.

An important factor for successful projection welding is the cleanliness of the material; *i.e.*, there should be no dirt, grease, oxide scale, or rust on the surfaces.

Projection sizes

Recommended projection shapes for welding flat mild steel sheet, based on experimental work by the

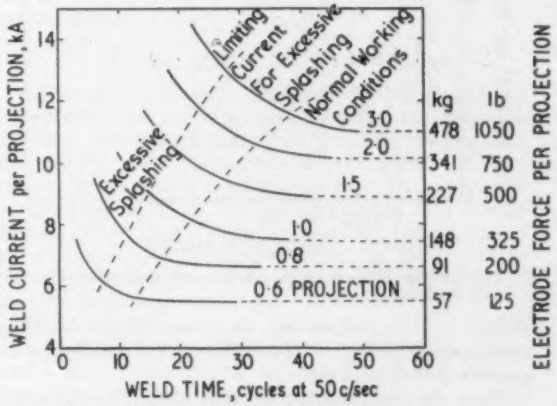


4—Dimensions of projections and punch and die

All dimensions follow a series of 'Preferred Numbers' in BS. 2045. Material thickness increases by 33%, series R80/11. Projection dimension *A* increases by 15%, series R80/5. Projection dimensions *B–F* increase by 12%, series R80/4.

The dimensions are approximate, with compatibility tolerances of ±0·003 in., (±0·08 mm), with the exception of *E*, which must remain to a close tolerance.

Dimension *D* is included for toolmaking purposes.



5—Range of conditions for projection welding mild steel sheet

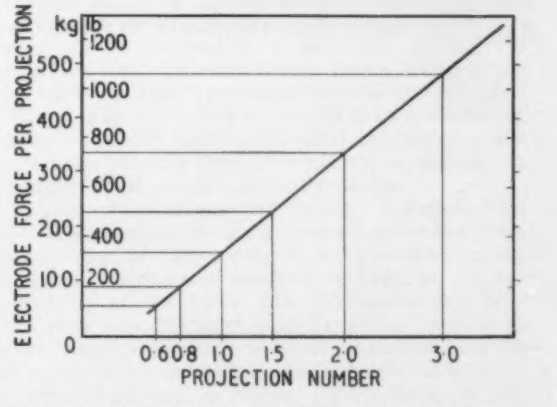
Table III

Projection welding conditions

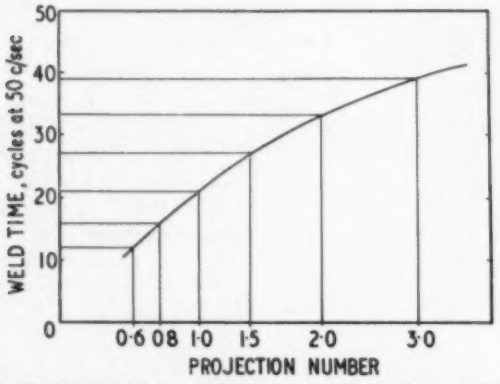
Sheet Thickness, in.	Projection Size	Electrode Load per Projection lb	kg	Time, c (50 c/sec) and corresponding Current per Projection, kA c	kA	c	kA	c	kA
0·021–0·027*	0·6	125	57	8	6·0	**13**	**5·8**	18	5·7
0·028–0·037	0·8	200	91	7	9·0	**17**	**7·0**	27	6·6
0·038–0·052	1·0	325	148	12	9·7	**22**	**8·2**	32	7·5
0·053–0·071	1·5	500	227	17	10·9	**27**	**9·7**	37	9·0
0·072–0·099	2·0	750	341	23	11·8	**33**	**10·7**	43	10·2
0·100–0·134	3·0	1050	478	28	12·9	**38**	**11·6**	48	11·0

* For welding two or three projections in the 0·6 projection size the current per projection should be 80% of the values given. Evidence in production suggests that these thicknesses are possibly just below the limit at which the projection shape specified is really suitable.

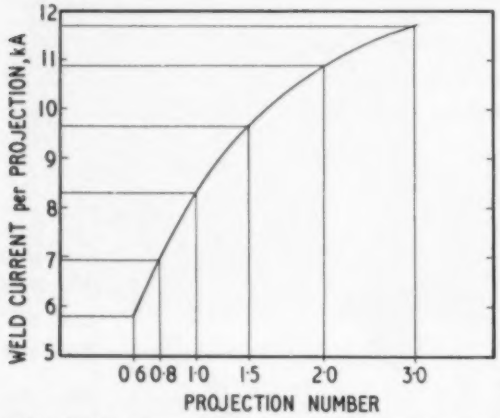
Bold figures are normal welding conditions.



6—Relationship between electrode force and projection size for mild steel sheet



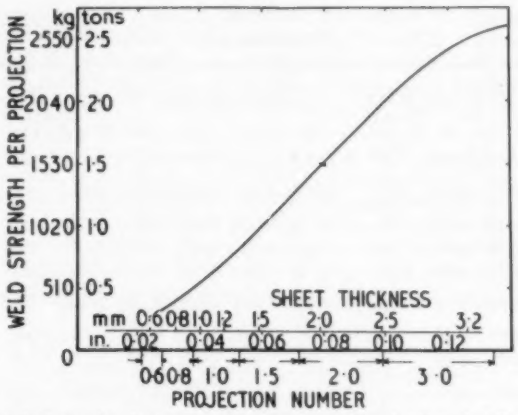
7—Relationship between weld time and projection size for mild steel sheet



8—Relationship between weld current and projection size for mild steel sheet

Research Association are given in Table II; the accompanying Fig. 4 shows also the outline of a suitable punch and die.

These are the preferred forms and can be used successfully for most applications. The accuracy of the projection heights in any one component is of prime importance, and to obtain the best results the individual heights should be within 0·001 in. of each other in each group of projections. The pitch of the projections



9—Relationship between weld strength and projection size for mild steel sheet

can have an important effect on the strength of the joint produced and on the welding conditions required. As the projection pitch is reduced, the tendency of individual welds to grow towards one another becomes more pronounced, and eventually a stage may be reached at which a single continuous weld would be formed. It is then better to use either a smaller number of individual projections or a different type of projection such as a line or **Y** form.

Welding conditions

A range of projection welding conditions for each projection size is given in Table III and by the curves in Fig. 5. The relationships between the normal welding conditions and projection sizes are shown in Figs. 6–8. The weld strengths shown in Fig. 9 are the minimum which may be consistently expected between two flat sheets using the proposed welding conditions; if other conditions giving lower strengths are adopted less consistency may also be expected. The exact strength obtained in any particular application will depend upon the design of the component being welded.

Burrs on the edges of pressings, and other distortions that might lead to the passage of current between the components at points other than the projections, must always be avoided, for any such current shunting will result in low and inconsistent weld strengths.

B.W.R.A. REPORT

Report on B.W.R.A. Questionnaire on Penetrameters

SYNOPSIS

Radiologists can obtain from this report information on penetrameters and their sensitivity, which cannot be found in most radiographic codes of practice on welding. Members of B.W.R.A. were asked to use two experimental penetrameters and to complete a questionnaire on them.

The first experimental penetrameter has 2-in. wires mounted in plastic; the second is a step-type with holes drilled in each step. The report summarizes the replies to the questionnaire.

Introduction

The FE.18 Radiographic Panel of B.W.R.A. has felt for some time that it would be desirable to issue guidance to radiologists on the subject of penetrameters and penetrameter sensitivity in more detail than is contained at present in most radiographic codes of practice concerned with welding. Experimental work recently reported by this Panel,[1] on the attainable sensitivity with commonly used penetrameters on steel thicknesses from ½ to 2 in., confirmed that the numerical values of sensitivity could vary widely, that some penetrameters were much more sensitive than others to changes in technique, and that the commonly quoted standard of 2% sensitivity was almost meaningless unless coupled to a particular design of penetrameter.

The same problem has been discussed by Commission V of the International Institute of Welding, and the French welding industry has given wide publicity to a new design of penetrameter, devised by Brachet,[2 3] for which considerable advantages are claimed.

None of the penetrameters in general use at present is entirely satisfactory, and two experimental types have been designed, both of which, it was thought, might have some advantages over those generally in use in Great Britain. To sound industrial opinion and to amass data, members of B.W.R.A. who had radiographic facilities were asked to co-operate by obtaining and using these penetrameters and completing a short questionnaire.

The questions were designed to discover whether members thought that either of the experimental penetrameters had any advantages over the type they then used, and whether they would have any objection if either of the new designs was introduced into specifications as a preferred type. Forms were also supplied on which members were asked to give details of their radiographic techniques and the penetrameter sensitivities attained on both established and experimental types.

Report FE.18RP/82/58 of the British Welding Research Association, issued to members in March 1958.

EXPERIMENTAL PENETRAMETERS

The experimental wire penetrameter has a series of eleven wires embedded in plastic. In the form produced for these tests the wires are 2 in. long and the plastic is not flexible. The thicknesses of the wires are in a geometric progression, as distinct from the arithmetic progression of D.I.N. wire penetrameters. The fundamental idea is that if there is a constant ratio between the thicknesses of successive wires, the 'difference in visibility' between successive wires should also be roughly constant.

The wire diameters, in inches, are: 0·004, 0·005, 0·0065, 0·008, 0·010, 0·013, 0·016, 0·020, 0·026, 0·032, and 0·040. These can be compared with a D.I.N.–1 penetrameter, the wires of which, in inches, are: 0·004, 0·006, 0·008, 0·010, 0·012, 0·014, and 0·016.

If the D.I.N.–1 penetrameter is used on a ½ in. weld, the first wire represents 0·8%, and the second 1·2%; this is a very large interval, whereas the experimental model has an intermediate wire. If, however, the same D.I.N. penetrameter is used with gamma-rays on a 1 in. weld, the thinner wires would probably not be visible and the three thickest wires would represent 1·2, 1·4, and 1·6%. This is thought to be too small an interval and may lead to difficulties in judging which wire represents the limit of visibility, so causing an inspector to obtain inconsistent readings.

The experimental step penetrameter is derived from the French design,[2] Basically there are one or two holes in each step, of diameter equal to the thickness of the step, and judgement of sensitivity is based on the discernibility of the holes. The thicknesses and hole diameters were modified from the French version to meet British drill sizes, and to simplify machining the steps were made rectangular. There are eleven steps of nominal thickness, in inches: 0·0135, 0·016, 0·020, 0·025, 0·032, 0·039, 0·0465, 0·0635, 0·0785, 0·098, and 0·120. The 0·098 in. step was miscut and was actually

0·087 in. in some specimens, and there are errors of up to ±0·002 in. reported in some of the other steps.

Each step is $\frac{1}{4} \times \frac{1}{2}$ in., making a total length of $2\frac{3}{4}$ in.; the thicknesses are in geometric progression, and in each of the four thinner steps there are two holes instead of one.

RESULTS

Sixty firms or organizations agreed to obtain the experimental penetrameters and 44 replies were received.

Experimental wire penetrameter

For this type there were 42 answers to the question, *Do you consider this penetrameter has advantages over the type of penetrameter which you usually use?* Of these, 20 were a clear *Yes*, 13 said *No*, and 9 replies were indeterminate. Of the *No's*, two objected only to the lack of flexibility of the plastic mount and several replies objected only to the overall size of the penetrameter. Some of the remaining objections are less easy to understand and are given below, with comment where possible.

(i) *Calculations of sensitivity are more difficult to make and a calculating table would help.* With a standard thickness of specimen, say 1·0 or 2·0 in., this may be a valid comment, but surely not all welds are so standard.

(ii) *Does not resemble any type of weld defect.*

(iii) *The penetrameter appears to give a rather optimistic view of sensitivity, giving twice the sensitivity obtained with the step type. I would doubt whether these high values are accurately representative of the actual sensitivity of fault detection.* This has never been claimed and is almost certainly not true for any penetrameter.

(iv) *Equal spacing tends to auto-suggestion.* This surely is true to some extent of most penetrameters but, in fact, the wires on this penetrameter are not equally spaced.

(v) *The identification of the wires is difficult when both the finest wires, owing to specimen thickness, and the thickest, by reason of position, are invisible.* This seems a valid criticism which could occasionally occur with awkwardly shaped specimens, but would be easily overcome by a lead marker on a chosen wire. This same reply suggested breaking up the wire penetrameter into three separate units, as with the D.I.N. type, but this, although useful for some classes of work, would remove many of its present advantages.

It would seem that if the wires were shorter and in a flexible mount, there would be only 8 replies out of 42 stating that in their opinion this penetrameter has no advantages over established types.

Experimental step-type penetrameter

In answer to the main question, as applied to this penetrameter, 41 replies were received. Of these, 20 stated that in their opinion this penetrameter has advantages over types at present in use, 9 were classified as 'neutral' and 12 said *No advantage*. The only complaint of 5 was that the penetrameter was too thick for use on specimens thinner than $\frac{1}{4}$ in. This is a limitation of most forms of drilled-hole penetrameter; the cost and difficulty of drilling holes and machining steps less than 0·01 in. is likely to be quite considerable.

Three of the replies gave no reasons, and two were not in favour because their work was principally concerned with pipe welds and the penetrameter is not flexible.

Again there were individual comments, some of which are not easy to appreciate:

(i) *There is no step representing 2% exactly.*

(ii) *The sensitivity is not as good as with the B.W.R.A. type.*

(iii) *Pitted plate tends to obliterate the holes.*

(iv) *The smaller holes were difficult to distinguish even on $\frac{1}{4}$ in. specimens, although in all cases the steps are clearly visible.* This ought to be a point greatly favouring the penetrameter. Through this thickness all the holes should be clearly visible and the penetrameter indicates that there is something wrong with the technique.

(v) *The writer concludes that the apparently higher sensitivity with the B.W.R.A. type is due to the help which the arrangement of the holes to form a number gives when viewing. This gives immediate recognition of the step thickness which is very useful. Cannot this principle be incorporated in the new type?* Probably it could, but the cost would be prohibitive.

(vi) *Wrong thickness range covered by steps and arithmetic type gives more accuracy.* This comment is not fully understood.

The opposition to this penetrameter is therefore a little more serious than that to the wire type. The most difficult point to overcome is the unsuitability for specimens less than $\frac{1}{2}$–$\frac{3}{4}$ in. thick, which could be covered only by a more expensive model. The other serious points raised were:

(i) Lack of flexibility. This might be overcome by making each step as a separate tablet embedded in a flexible mount, but the result would probably be cumbersome

(ii) The effect of beam angle in relation to the axis of the drilled holes, in affecting sensitivity as judged by a penetrameter placed off-centre. No evidence was offered to show how serious this might be

(iii) The unsuitability of this penetrameter for welds having a large reinforcement, in that a penetrameter laid alongside the weld is not on the true metal thickness. This could be overcome, if necessary with equalizing strips, but it is a limitation common to all step penetrameters.

General comments

It is quite clear from the questionnaires that most radiologists at present use the B.W.R.A. type of penetrameter, the actual numbers being:

B.W.R.A. (drilled holes of constant size to form figures in each step)	29
D.I.N. (wire)	9
A.S.M.E. (single hole of constant size, in each step)	5
Own or other special type	5

A proportion of the users of the B.W.R.A. type stated specifically that their judgement of sensitivity is based on the visibility of a step rather than the holes, and this must be a cause of some confusion. Other general comments were made which throw light on the attitude of some users towards penetrameters:

(i) *It is rather disturbing to find that three different penetrameters can give a variation of penetrameter sensitivity of the order of 1·9% when used under the same conditions.*

(ii) *Any penetrameter should have a suitable step to assess, accurately, 2% sensitivity at that thickness. A penetrameter capable of covering a range of thickness could be the cause of controversy . . . as to the sensitivity obtained.*

(iii) *The step-penetrameter gives too low a sensitivity, whilst the present B.W.R.A. type gives one that is too high, especially for fine linear defects.*

These comments seem to indicate considerable ignorance of the purpose of a penetrameter, and that there is thought to be some magic in the value of 2%. There seems to be a lack of recognition that the prime purpose of a good design of penetrameter should be to

indicate changes in technique, such as shortening of s.f.d., or use of an unsuitable isotope. Provided that these changes cause a corresponding change in penetrameter sensitivity it does not matter whether the change is from 0·5 to 0·7% or from 3 to 4%.

On the subject of different sensitivities with different penetrameters, one reporter's comment is worth quoting in full: *We are governed by clients' requirements on choice of penetrameters but I would personally like to add that even with identical radiographic techniques, the numerical value of penetrameter sensitivity will differ with each type, including the two new types. Therefore the possibility of variance of opinion between contracting parties is still very much with us, and in some cases, particularly on . . . , the problem is critical.*

EXPOSURE DATA

Almost all replies contained valuable data indicating the techniques in general use for different thicknesses, and the sensitivities obtained. Some data had to be rejected because of obvious miscalculations; for example 1% and 2% was claimed with the experimental step penetrameter on $\frac{1}{2}$ in. steel, although the thinnest step represents 2·7%.

Out of over 250 techniques listed, about 45% were on fine-grain film, 40% on medium-speed film and the remainder divided between salt-screens, high-speed non-screen, and ultra-fine-grain film techniques.

Apart from a few outstanding examples, the vast majority of techniques were such as would lead to radiographs of reasonable quality. The exceptions were: one suggestion of using iridium–192 on $\frac{1}{16}$ in. steel and caesium–137 on $\frac{3}{8}$ in. steel; and two others using iridium–192 on $\frac{1}{4}$ in. steel. The techniques quoted for 3–4 in. steel were all on fine-grain film. One reporter used a combination of salt and lead screens, with X-rays for $\frac{1}{2}$–$1\frac{1}{2}$ in. steel, but also quoted considerably improved sensitivities, with the same apparatus, using medium-speed, direct-type film with lead screens.

Neglecting these abnormal techniques, however, there was a reasonable consistency of results on most. Variations in sensitivity could usually be clearly attributed to some difference in technique. Considering, as an example, gamma-radiography with iridium–192 on 1 in. steel, the following percentage sensitivities were listed, each by a different reporter:

Experimental penetrameters		*B.W.R.A.*
Wire	*Step*	*penetrameter*
Fine-grain film		
1·3	2·5	2·8
1·3	3·2	3·0
1·3	2·5	2·0
1·3	2·5	2·0
1·6	2·5	1·3
1·3	2·5	3·0
1·6	3·9	1·0
Medium-speed film		
1·3	4·0	—
1·6	3·2	3·0
1·6	3·2	3·0
1·78	2·8	—
1·6	3·2	2·0
1·3	3·2	3·0

All exposures were made at distances between 18 and 24 in. with a 4×4 mm source, or at equivalent distances with a smaller source.

With the wire penetrameter there is much less spread of results than with either of the others, but both experimental types quite clearly distinguish between the two different types of film. The experimental step penetrameter distinguishes most clearly between the two techniques.

Estimates of attainable sensitivity

Sufficient data are available from the questionnaires to make reliable estimates of the sensitivities that can be obtained with different techniques, using the two experimental penetrameters. The techniques have been sub-divided in the same way as in BS.2910:1957:

1. X-rays, using screen-type film, with salt intensifying screens
2. X-rays, using medium-speed direct-type film, with lead screens. (High-speed direct-type film is not included)
3. X-rays, using fine-grain, high-contrast film with lead screens
4. Gamma-rays, using medium-speed, direct-type film with lead screens
5. Gamma-rays, using fine-grain, high-contrast film with lead screens.

The spread of results for thicknesses of $\frac{1}{2}$, 1, 2, 3, 4 in. of steel, shown in Table I, is in most instances quite small, so that a value can be assigned to the sensitivity that can be expected using either of the experimental penetrameters. These values would be

Table I

Percentage sensitivities in steel, using experimental wire and step penetrameters

(These can be used as standard attainable values)

Specimen Thickness, in.	*Technique*									
	1		*2*		*3*		*4*		*5*	
	X-rays, Salt Screens		*X-rays, Medium-speed Film*		*X-rays, Fine-grain Film*		*Gamma-rays, Medium-speed Film*		*Gamma-rays, Fine-grain Film*	
	Wire	*Step*	*Wire*	*Step*	*Wire*	*Step*	*Wire*	*Step*	*Wire*	*Step*
$\frac{1}{2}$	1·0*	—	1·3	3·0	1·0	2·7	2·6	5·0	2·4	4·6
1	1·3	2·5	1·1	2·3	0·9	2·0	1·6	3·0	1·3	2·5
2	1·1	2·3	1·0	1·8	0·8	1·6	1·5	2·5	1·3	2·0
3	1·3*	2·8*	1·0	1·6	0·7	1·5	1·3	2·2*	1·0	2·0
4	–	–	–	–	0·6	1·2	–	–	0·8	2·0

*Tentative values, as only small amount of data available

suitable for use by an inspection authority, in a specification, to ensure that a particular technique is being used and an adequate sensitivity is maintained, within much closer limits than are generally possible at present. The main requirement is the specifying of a particular penetrameter type.

The values shown in Table I are not the best possible values of sensitivity, since by careful attention to detail they can easily be improved. They should rather be regarded as values which, if not achieved, indicate that there is some error in the technique claimed to be employed.

A few results on extra-fine-grain film with gamma-rays gave an improved sensitivity compared with fine-grain film, particularly on thinner sections. Also a few results on high-speed direct-type film with X-rays showed a loss in sensitivity, compared with the use of medium-speed film.

Although a number of techniques were quoted, no sensitivity values can be included for $\frac{1}{4}$ in. steel, for with both penetrameters the thinnest element should be visible.

CONCLUSIONS

Wire penetrameter

1. If the wire penetrameter were to be made using the same wire thicknesses as the present experimental model, but with shorter wires (say $1\frac{1}{4}$ in. long), and in a flexible mount, there would be little opposition to its adoption as a standard type. The penetrameter would need to have an identification mark embedded in the mount, and it would be advantageous also to have a small marker opposite a pre-determined wire near the middle of the series.

2. It is sensitive to changes in technique, but does not give a constant percentage sensitivity over a wide thickness range, the numerical percentage sensitivity decreasing with larger specimen thicknesses.

3. This one-wire penetrameter is suitable for specimen thicknesses from $\frac{1}{4}$ in. to about 6 in., using any reasonable X- or gamma-ray technique.

4. By the addition of two more thin wires, say 44 and 46 s.w.g., the one single penetrameter could be made suitable for specimen thicknesses down to about $\frac{1}{8}$ in.

Step penetrameter

5. Although it was approved by a majority of the replies this experimental penetrameter attracted some serious criticism.

It is insuitable for use on specimens thinner than about $\frac{1}{2}$ in., and for curved surfaces; and from some replies, it seemed to cause some confusion in judging sensitivity because, with certain techniques, a step could be clearly seen when the hole in the same step was not discernible. These criticisms are not easy to overcome and it would seem that this type of penetrameter is more limited in applicability.

6. The penetrameter distinguishes between different techniques very adequately and in this respect it is probably more sensitive to factors affecting radiographic definition than is the wire type. It does not give a constant percentage sensitivity over a range of thicknesses.

(It should be noted that the sensitivities obtained with the two penetrameters are very different.)

7. It can be used on thicknesses from $\frac{1}{2}$ in. to at least 10 in., but to make it suitable for use on thinner specimens would involve expensive additional machining.

General

A mass of sensitivity data has been collected and could be utilized to form a firm basis for the production of future recommendations or specifications on radiography.

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Continued from p. 582

RADIOGRAPHS OF ALUMINIUM WELDS

Inspectors, welding engineers, designers, and fabricators of aluminium alloys will be interested in a new booklet H3/58, published by the British Welding Research Association, which shows how to indentify the defects in aluminium fusion welds that can be seen in radiographs. The defects are classified, their origin is explained, and suggestions for their prevention are made. The booklet was prepared by the senior metallurgists of B.W.R.A. helped by a panel of experts from industry.

Many more defects can exist in aluminium alloys than in mild steel, mainly because fabrication is possible by several different processes. The devising of a logical system for classifying these defects is therefore, a step forward. The book recognizes five groups of defects:

1. Cracks
2. Lack of fusion, including incomplete root penetration
3. Voids, including the three types of porosity, uniform, localized and linear, as well as elongated cavities and crater pipes
4. Inclusions of oxide, flux, or metal, the latter usually tungsten but sometimes copper or iron
5. Imperfect shape, including defects (which may, or may not, be seen on visual inspection, depending on the joint design) such as undercut, excessive penetration, and root shrinkage.

Surface marks give characteristic shadows in radiographs, and they are therefore included though they are not defects.

General indications are given of the ways in which the defects influence joint properties, but except for uniform porosity this is only qualitative. A simple system is given for recording the severity of uniform porosity and its probable effect on joint efficiency. No attempt has been made to indicate acceptance standards though the booklet may well form a useful basis for discussions on such standards.

The booklet entitled "Classified radiographs for defects in aluminium fusion welds" is free to members of the Association until 1st February, 1959, and the cost to non-members is 10*s*.

Welding

RESEARCH

Calculating Hot Cracking Resistance of High Tensile Alloy Steel

DURING ARGON-ARC WELDING

By

F. J. Wilkinson, B.Sc., A.M.I.Mech.E., A.M.I.E.E.,

C. L. M. Cottrell, M.Sc., Ph.D., A.I.M., and H. V. Huxley

SYNOPSIS

A study is made of the effect of steel composition on hot cracking during argon-arc welding of alloy steel sheet. The adverse effect of carbon, phosphorus, silicon, and nickel is noted. It is suggested that the adverse effect of these elements is reduced by the presence of manganese, chromium, molybdenum, and vanadium.

A formula has been derived by which the hot crack sensitivity of alloy steels may be assessed from their composition.

WELDED joints in high-tensile alloy steels are normally required to withstand high working stresses; that such welded joints should be sound is clearly of prime importance.

Steels of the 1% Cr–Mo type have been welded with considerable success for a number of years using the argon-shielded tungsten-arc process. A long experience in the welding of one such steel, to Bristol specification RS. 120, shows it to vary in its 'weldability'; the major difficulty found in some batches being a tendency to hot cracking either in the weld or parent metal.

A recent paper[1] has demonstrated that the cracking is caused primarily by sulphur. This element forms low melting point segregates along the grain boundaries, the segregation being assisted by the presence of phosphorus. With increasing carbon the tolerable limits of sulphur and phosphorus decrease.

It has been known or suspected for some time that other elements also affect the hot crack sensitivity of a steel; for example, Mn is beneficial. Reeve,[2] and Rollason and Roberts[3] consider that silicon has an adverse affect, and the latter also suggest that silicon assists in the segregation of sulphur.

To investigate further the effect of composition on susceptibility to hot cracking, eleven steels in sheet form and of widely varying composition have been examined, using a modified form of a crack sensitivity test developed by Houldcroft.[4]

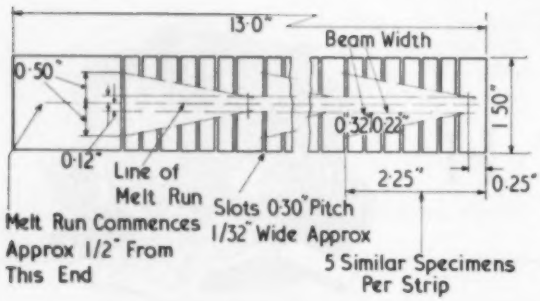
DESCRIPTION OF TEST

The crack test specimen, which contains five actual test pieces, is illustrated in Figs. 1 and 2.

The mechanism of the test is associated with the heat flow in the specimen. A melt run is commenced at the position shown in Fig. 1 (in tests on parent metal, filler wire is, of course, not used). As the weld pool moves along the specimen an 'edge starting' effect is obtained by the first pair of slots, which extend to within $\frac{1}{8}$ in. of the centre. Owing to the build up of thermal strain, a crack starts at this point and is propagated by the continued thermal strain on the melt run. The effect of the remaining slots in each test piece is to

Manuscript received 28th August 1958.

Mr. Wilkinson is Assistant Chief Engineer, Dr. Cottrell is Welding and Research Engineer, and Mr. Huxley is a Development Engineer in the Weston Division (Rocket Motors) of Bristol Aircraft Ltd.



1—Dimensions of crack test for strip steel

2—Crack test specimens

reduce this strain gradually without interfering with the thermal distribution. Depending on the crack sensitivity of the material under test, a point is eventually reached where the strain is insufficient to continue the propagation of the crack.

Crack sensitivity is defined as 'beam width'. This is, in effect, a measurement of the strain on the melt run at the point where the crack ceases to propagate. The measurement illustrated in Fig. 1 is the distance from (and perpendicular to) the melt run at the end of the crack to a line joining the inside ends of the strain-reducing slots. The beam width on both sides of the melt run is measured, and the mean of the two readings is adopted.

For the test results to be comparable, it is important that the welding speed and current should be kept constant, although the measurement of beam width takes some account of the weld width, which is a function of current and welding speed.

MATERIAL

The composition of the eleven steels examined is shown in Table I, together with the current requirements of Bristol specification RS. 120.

Steels 1–4 were supplied to an earlier issue of the specification, which allowed higher contents of sulphur and phosphorus, and lower carbon than that now specified. They were selected for test because of

Table I

Steel compositions

No.	*Batch No.*	*Specification*	*Analysis, %* *C*	*Mn*	*Si*	*S*	*P*	*Ni*	*Cr*	*Mo*	*V*
1	A675	RS. 120	0·33	0·51	0·15	0·015	0·023	0·15	0·91	0·20	—
2	9912	RS. 120	0·31	0·55	0·36	0·007	0·020	0·12	0·86	0·19	—
3	9916	RS. 120	0·28	0·55	0·28	0·008	0·018	0·12	0·95	0·25	—
4	5854	RS. 120	0·31	0·42	0·22	0·017	0·034	0·17	0·85	0·24	—
5	—	En. 19	0·36	0·60	0·16	0·007	0·018	0·30	1·17	0·285	—
6	—	En. 40B	0·24	0·48	0·20	0·013	0·014	0·16	3·04	0·53	—
7	—	En. 40C	0·38	0·63	0·33	0·008	0·013	0·19	3·13	0·87	0·24
8	—	Rex. 539	0·35	1·57	1·55	0·011	0·018	1·80	0·11	0·34	0·21
9	—	SAE.4335	0·32	0·64	0·18	0·011	0·020	1·90	0·85	0·22	—
10	—	Firth F.G.	0·21	0·35	0·23	0·014	0·025	0·26	12·92	—	—
11	—	M.O.G. 510	0·37	0·41	1·10	0·012	0·014	0·22	4·9	1·50	0·54
Requirements of Bristol Specification RS. 120			0·30 min. 0·35 max.	0·40 min. 0·60 max.	0·20 min 0·35 max.	— 0·015 max.	— 0·025 max	— 0·30 max.	0·80 min. 1·0 max.	0·15 min. 0·25 max.	— —

their varying crack sensitivity as shown by experience in production. Steels 5–11 were samples obtained for a variety of experimental purposes and therefore have no history of weldability in production. All eleven steels were in the spheroidized condition and were supplied in thicknesses from 16 s.w.g. to $\frac{1}{8}$ in., the thicker steels being reduced for testing to 16 s.w.g. by surface grinding.

By examining the steel at a magnification of 2000, each steel was classified according to the degree of carbide coalescence, as follows:

Size 1 = 0 to 1 mm dia. of carbide particle
Size 2 = 1 to 2 mm
Size 3 = 2 to 3 mm
Size 4 = 3 to 4 mm

The size of carbide thus assigned to each steel is given in Table II. This estimation was made since it was considered that any marked variation in carbide size would affect the steels' hot crack sensitivity. Where the carbide particles are large the parent metal heat-affected zone does not remain at solution temperature long enough to effect solution of carbides, resulting in a lower effective carbon content; this reduction in effective carbon leads to reduced hot crack sensitivity in the heat-affected zone.

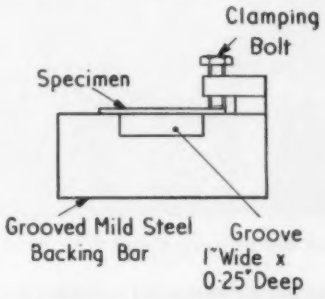
Table II
Degree of carbide coalescence

Steel No	*Carbide size*
1	1
2	1 to 2
3	1 to 2
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1

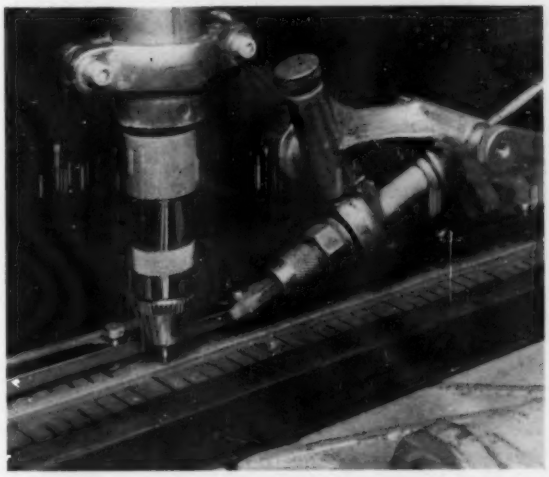
TEST PROCEDURE

The specimen made from 16 s.w.g. material was set up in the combined holding jig and backing bar shown, in section, in Fig. 3. Figure 4, illustrating the specimen in the welding machine preparatory to making a test run, shows that each test piece was held by one clamping bolt and was, in effect, unrestrained during the test.

The welds were made by the argon-arc process



3—Holding jig and backing bar for crack test



4—Crack test assembly

using an automatic head, at a welding speed of approx. 5 in./min, and a current of approx. 74 amp.

After the completion of a melt run, the specimen was allowed to cool to room temperature, and the beam width on each of the five tests was measured with a travelling microscope incorporating a vernier scale.

The index of hot cracking resistance for the steel under test was determined from the average of beam width readings for a minimum of five tests on one specimen.

RESULTS

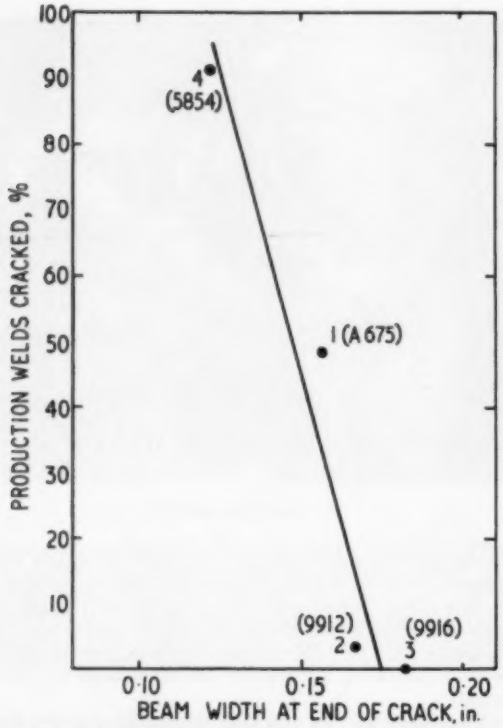
Although, initially, the same number of tests were made on each steel, some were discarded because of poor penetration or failure to initiate proper cracking.

Table III shows the average beam width values obtained on the eleven steels listed in Table I. The greater the beam width value, the greater was the cracking resistance of the particular steel.

An indication of the hot crack sensitivity of the four RS. 120 steels, assessed by a study of their production welding history, is also given in Table III. This is expressed in terms of the percentage of sheets showing

Table III
Crack test results

Steel	*Batch*	*Specification*	*Number of Beam width readings*	*Average Beam width, in.*	*Production Welding History*	
					No. of Sheets Welded	*Percentage cracked*
1	A675	RS. 120	16	0·157	188	48·5
2	9912	RS. 120	16	0·167	57	3·5
3	9916	RS. 120	8	0·182	39	nil
4	5854	RS. 120	12	0·122	23	91·3
5	—	En. 19	8	0·195	—	—
6	—	En. 40B	8	0·305	—	—
7	—	En. 40C	18	0·232	—	—
8	—	Rex. 539	8	0·149	—	—
9	—	SAE. 4335	20	0·135	—	—
10	—	Firth F.G.	17	0·40	—	—
11	—	M.O.G. 510	24	0·183	—	—



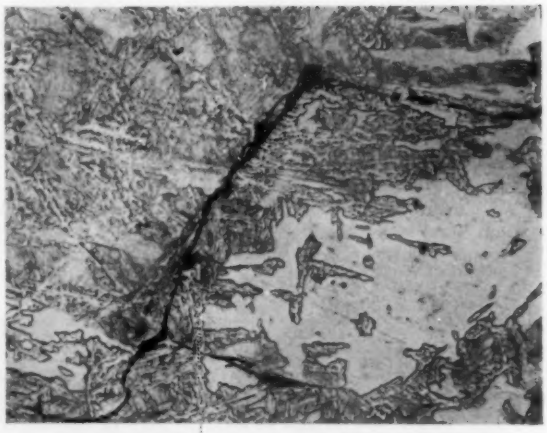
5—Relationship between cracking in production and results in crack test for 1% Cr–Mo steel

at least one crack in the welded joints as determined by X-ray examination.

Figure 5 relates the production crack sensitivity (Col. 7, Table III) to the cracking resistance determined by beam width on the Houldcroft test.

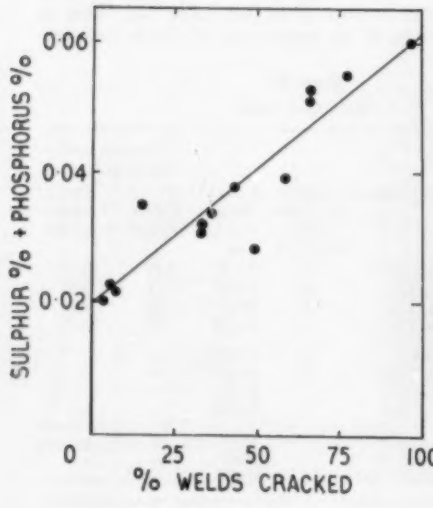
DISCUSSION

The relationship between crack sensitivity, as shown by the production welding history of the four RS.120



6—Grain boundary crack. Etched in 2% Nital ×500

7—Crack and inclusions. Etched in 2% Nital ×500



9—Relationship between sulphur plus phosphorus and cracking for 1% Cr–Mo steel containing 0·3% C

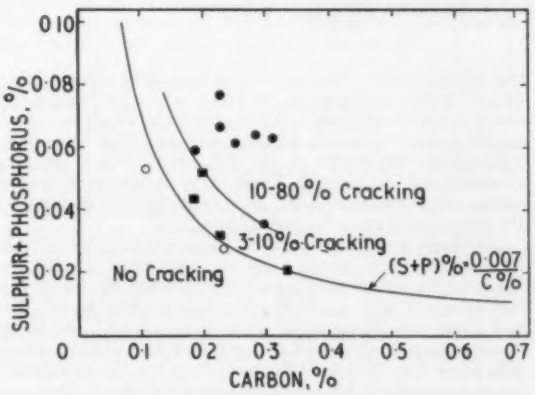
8—Hot cracks near weld boundary. Etched in 2% Nital ×7½

steels 1–4, and the cracking resistance for the same steels obtained from the Houldcroft test (Fig. 5) shows the test to be quite selective, bearing in mind the uncontrollable variables that are bound to exist in production welding. Steels 2 and 3 show rather less cracking in production than would be expected from the Houldcroft hot crack test results. This could be due to the reduction of heat-affected zone cracking caused by the modifying effect on carbon content of the larger carbide size in these two steels (Table I). In the crack test, cracking occurs in the weld or melt run, and the carbides should be in solution; but in the production welding of these steels a C–Mn filler metal was used which gave a crack-resistant deposit, thereby localizing hot cracking mainly in the heat-affected zone, as shown in Fig. 8, so that the crack sensitivity of this zone was affected by the carbide size of the parent metal. This effect would not be apparent when parent metal filler is used. The greater crack resistance of spheroidized steels has been reported by Voldrich and Williams.[5]

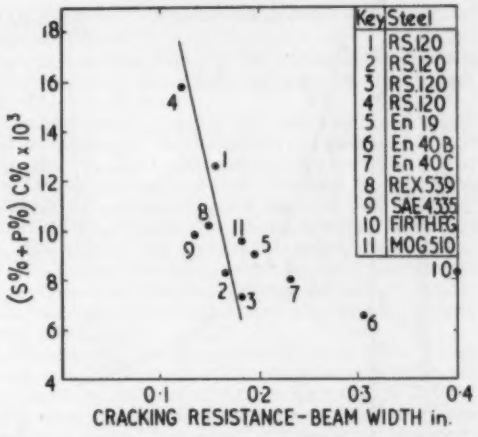
Typical examples of the type of cracking experienced in the welding of 1% Cr–Mo steel sheet are shown in Figs. 6, 7 and 8. In Fig. 6 the cracks are clearly intergranular as also are those shown in Fig. 7, but the latter are associated with inclusions giving rise to a network of cracks. The hot cracks near the weld boundary shown in Fig. 8 have clearly widened while the metal was in a hot-plastic condition.

Figure 9 shows the percentage of cracked welds occurring in a 1% Cr–Mo steel containing 0·3% C but with various levels of sulphur and phosphorus. The relationship shown is in very good agreement with some work done in Germany more than twenty years ago by Bollenrath and Cornelius,[6] from which the data shown in Fig. 10 were derived.

Wilkinson and Cottrell[1] suggest that to avoid cracking the factor sulphur%+phosphorus% must be less than 0·007/C%. In Fig. 12 the cracking resistance values of the eleven steels obtained from the Houldcroft test are plotted against the function C%(S%+P%). Whilst the relationship appears to hold good, at least for some of the steels examined, the positions of steels 5, 6, 7, 9, and 10 suggest that the relationship is more complex.



10—Relationship between S+P, carbon, and cracking in 1% Cr–Mo steel



11—Hot crack resistance of alloy steels, related to S, P, and C content

Despite similar sulphur and phosphorus contents and a higher carbon content, steel 5 shows appreciably better crack resistance than does steel 2. Examination of the composition of the two steels shows that steel 2 has a higher silicon content, whilst steel 5 has higher chromium and manganese contents.

The very much greater crack resistance of steel 6 compared with steel 2 is also considered to be significant, and again the appreciably higher chromium content seems to be influential. Steel 6 also has a somewhat higher molybdenum content than steel 2.

In addition to the suggestion of Rollason and Roberts[3] that silicon adversely affects hot cracking these authors state that a nickel content as low as 0·5% can also have an adverse effect, and suggest that nickel is associated with the presence of sulphide films around the grain boundaries. It is therefore interesting to note the poor crack resistance of steel 8, which has high nickel and silicon contents. Further evidence of the adverse effect of nickel is also provided by steel 9.

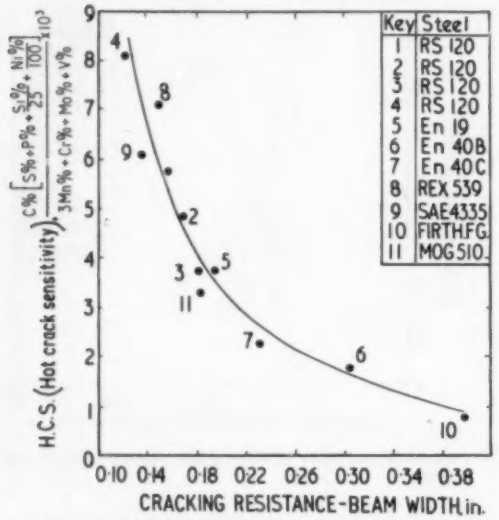
Most authorities consider that manganese reduces the severity of hot cracking, and it is evident that the beneficial effect of this element should be considered in devising a formula for hot crack sensitivity.

The beneficial effect of the carbide forming element chromium is seen to be marked, possibly because of its effect on carbon. For this reason, the elements molybdenum and vanadium are also considered to be beneficial.

From a study of the compositions of the eleven steels tested, and their hot crack sensitivity as measured by the Houldcroft test, the following formula has been derived (the elements being expressed in percentages of the steel composition):

$$\frac{C\{S+P+(Si/25)+(Ni/100)\}}{3Mn+Cr+Mo+V}\times 10^3 = H.C.S.$$

The H.C.S. value for each steel, so obtained, is plotted against the actual crack resistance in Fig. 12. In comparing the values with the production welding results, shown in Fig. 5, it is clear that for satisfactory welding the H.C.S. value of a steel should be less than 4.


H.C.S. (Hot crack sensitivity) = C% + [S% + P% + Si%/25 + Ni%/100] / [3Mn% + Cr% + Mo% + V%] x10³
Key | Steel
1 RS 120
2 RS 120
3 RS 120
4 RS 120
5 En 19
6 En 40B
7 En 40C
8 REX 539
9 SAE4335
10 FIRTH F.G.
11 MOG 510
0·10 0·14 0·18 0·22 0·26 0·30 0·34 0·38
CRACKING RESISTANCE-BEAM WIDTH, in.

12—Effect of steel composition on hot crack resistance

It should be noted that the welding speed for the tests was measured only approximately. It is therefore intended to make further tests with varying speeds so as to examine the findings of Terry and Tyler,[7] who showed that welding speed affected hot cracking, and so to determine the effect of speed on the H.C.S. formula.

CONCLUSIONS

A formula has been developed whereby the hot crack sensitivity of a steel may be assessed from its composition. The formula applies to weld metal and can also be used to determine the crack sensitivity of the heat-affected zone.

When the parent metal is in the spheroidized condition, the heat-affected zone should show improved resistance to hot cracking when the carbide particles are large.

When the H.C.S. value is less than 4 a high degree of resistance to hot cracking is observed during the welding of alloy steels by the argon-arc process.

The superiority, with respect to resistance to hot cracking, of steels containing 3–5% chromium with molybdenum and/or vanadium has been demonstrated. Steels of this type appear to be capable of development as high-strength weldable steels in preference to steels containing nickel.

ACKNOWLEDGMENT

The authors would like to thank the directors of Bristol Aircraft Ltd. for permission to publish this paper.

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LETTERS TO THE EDITOR

Welding of Cupro-Nickel and Aluminium Bronze Alloys

The paper by C. A. Terry and E. A Taylor* is concerned with butt welding tests carried out by the tungsten-arc process and with hot-cracking tests on various aluminium bronzes and Superston. Conclusions are drawn concerning the susceptibility to hot cracking of these materials during welding: we wish to refer in particular to the statement that a Superston alloy is more susceptible to hot cracking than are the aluminium bronzes. We have had considerable experience of welding with Superston alloys, both in the laboratory and in practice. The alloys have also been used widely by other companies for applications involving welding. In no instance has there been any experience of cracking, and this is supported by the authors' statement on p. 219 that defect-free welds were made using Superston containing 8% Al, which is in accordance with our standard Superston 40. The conclusions regarding susceptibility to hot cracking appear to be based solely on results obtained in the Houldcroft test, the validity of which we would question, and for which an alloy was used that was not in accordance with either of the two compositions we have standardized for welding. There is no indication as to the source of the materials used, and we can only presume that the alloys were made by the authors.

Although there is a range of Superston alloys available for a variety of purposes, only two have been selected for the manufacture of welding wire: Superston 40, which is a high-strength alloy of duplex structure containing 8% Al; and Superston 10, an alpha alloy containing 4% Al. Both of these have been found to have excellent welding characteristics. The alloy used by the authors for the Houldcroft test contained 6% Al, which was an unfortunate choice in that it produces structures containing very small proportions of the undesirable beta phase. The mechanical test

* C. A. Terry and E. A. Taylor: *Brit. Weld. J.*, 1958, vol. 5, pp. 211–225.

results quoted in Table II are very inferior to those we would have expected from good quality material. For example, typical results obtained from welds in Superston 40 made by us and other people are as follows:

	0·1% Proof Stress, tons/sq.in.	*Tensile Strength, tons/sq.in.*	*Elong., %*
Flux coated, metal arc	21·8	44·4	27*
Flux coated, metal arc	—	49·1	19
Flux coated, metal arc	—	48·8	19
Argonaut	—	53·2	26
Argonaut	—	52·4	28

* Broke outside weld

We are aware that the alloy is not an easy one to produce, and can only presume that the material used was not up to standard.

We would now comment on the validity of the Houldcroft test for the purpose for which it was used by the authors. There is a complete contradiction between the results obtained with this test and those obtained with actual butt welds. In the former the only material to show freedom from hot cracking was the 93/7 aluminium bronze, which was the only alloy to crack during butt welding. In our view it is not satisfactory to dismiss such results merely with the comment that the special 93/7 filler alloy must be regarded as suspect. While accepting that the Houldcroft test might be excellent for examining the effects of impurities in a given alloy and has apparently given satisfactory results with certain aluminium alloys, we question its suitability for comparing materials between which there are distinct differences. Our own laboratory tests on susceptibility to hot cracking have been made on 6 in. square specimens of $\frac{3}{8}$ in. thick plate, from which 2 in. dia. discs were trepanned and then welded back into position. Under these onerous conditions no cracking was experienced with either Superston 40 or Superston 10.

We were surprised to read that work of the B.N.F.M.R.A. had shown lithium additions to have a beneficial effect on the hot-cracking tendencies of the aluminium bronzes, since the concluding paragraph of the final report, RRA.877, was:

> "Lithium additions to alpha-phase aluminium bronze metallic arc welding electrodes cause marked cracking of the weld deposit, and the effect is probably due to grain boundary inclusions associated with the presence of lithium."

Attention is therefore drawn to the inconsistency between this conclusion and the results obtained by the authors with the Houldcroft test.

The embrittlement of welds has been attributed to the presence of impurities, or alternatively to the formation of the γ_2 phase. The authors support the former view on the basis of their heat-treatment tests, in which welded pieces were heated to various temperatures and were then air cooled. The observation that those samples heated at 610°C. were slightly less ductile than others does not exclude γ_2 formation from being the cause, since reformation of the γ_2 phase would be dependent on the rate of cooling. It would have been interesting if more detailed information had been provided.

It is obvious that the proportion of the γ_2 phase which can occur in a 7% aluminium bronze weld must be small, but how have the authors arrived at the value of $1\frac{1}{2}$% of any beta retained, for this cannot be deduced from the equilibrium diagram? Regardless of proportion, however, it must be remembered that it is the disposition of a phase that is significant, and that very small proportions of a brittle grain-boundary phase can be very damaging.

We cannot understand the reasoning behind the authors' suggestion that if point *D* in Fig. 6 could be slightly displaced to the left, without altering equilibrium at lower temperatures, under no circumstances could γ_2 phase arise in subsequent reheating by decomposition of the beta phase: some amplification of this would be of interest, as we believe that if point *D* were displaced to a lower aluminium content the proportion of beta phase in the alloy would be increased, and the likelihood of gamma formation would be at least as great. A more effective method of preventing gamma formation is to alter the beta phase in such a way that it does not decompose eutectoidally. This is achieved by adding to the alloy a large proportion of manganese, and in the case of Superston alloys, which contain 12% Mn, the beta phase cannot be induced to break down, even if cooling rates are as low as 7°C./hr. Thus there never need be fear of the embrittlement of a Superston weld on this account.

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We are grateful for these comments on our paper and for the data about the welding behaviour of Superston alloys, which we are sure will be of general interest. We have no experience with this group of alloys, and Superston was included in our range of filler compositions only because of its reported low hot-cracking susceptibility. However, before we deal in detail with their comments we feel it would be of value to restate the purpose of our paper.

At the outset it was intended as a review of current welding practice applied to aluminium bronzes and cupronickel alloys. But during its preparation, reports of difficulties in welding of aluminium bronze were received from fabricators, apparently connected with hot cracking and weld-metal brittleness in multi-pass welds,[1] although no such problems had been encountered in earlier work.[2 3] An attempt was therefore made in the very limited time at our disposal to examine these problems experimentally.

There is an error in our paper, which unfortunately escaped correction in the proof reading: The aluminium content of Superston stated in Table IX should have been 8% and not 6%. Analyses of the two Superston alloys, which were not available in time for publication, show the aluminium contents to be 8·21% and 8·10% respectively (Tables VIII and IX).

The detailed comments will be dealt with for convenience under four headings: hot cracking and the Houldcroft test; the composition of Superston; the influence of lithium on hot cracking of aluminium bronze; and constitutional effects in aluminium bronzes.

Hot cracking and the Houldcroft test

It seemed likely from reports received[1] that cracking was of the super-solidus type. The Houldcroft test was therefore applied together with other tests designed to measure this type of cracking. Only the Houldcroft test was sufficiently discriminating to show that there were differences in the crack susceptibility of the alloys examined. The ease with which the severity of the test can be increased by reducing the width of the specimens is a particular merit. The dimensions finally selected for our work were those which preliminary work indicated were the most severe for the welding conditions employed. Nevertheless, super-solidus cracking in all the alloys was very slight and would in our opinion be insufficient to cause trouble in normal welding operations. Thus, it is not surprising that no cracking of Superston occurs in practice. We would point out that except for an isolated instance no cracking was encountered in any of the butt welding trials reported in the paper.

It seems fair to state, therefore, that:

(*a*) The Houldcroft test is capable of discriminating between the super-solidus cracking tendencies of the alloys examined

(*b*) The super-solidus cracking tendency of these alloys is so small that no practical welding problems from this source are likely.

On this basis it would be unreasonable to expect a correlation between the Houldcroft tests and ordinary welding trials, since the conditions for the latter will be insufficiently discriminating.

We agree that cracking occurred in a weld made with a 93/7 aluminium bronze filler. However, this material was not standard 93/7, and for this reason we labelled it 'special' (*see* Table VIII, page 218). Butt welds made with standard material did not in any instance exhibit cracking, a result which confirmed earlier work.[2] We drew attention to the result obtained with the special 93/7, firstly because the cracking was demonstrably sub-solidus and was the first instance in inert-gas shielded-arc welds that we had encountered, and secondly because we thought it highly probable that the cracking might be connected with compositional differences between the two materials. We hope that any future work will include a study of the influence of iron content on the weldability of aluminium bronzes, for it is a common constituent of modern alloys.

Composition of Superston alloys

We must apologize for the misunderstanding caused by our error in quoting the aluminium content of the Superston alloy in Table IX as 6% rather than 8%. The comment concerning the alloy containing 6% Al are therefore not relevant to the alloys used in our investigation. Nevertheless some extension of our correspondents' remarks that the 6% Al alloy is an unfortunate choice would be of interest, particularly in view of the penultimate sentence of their letter. Nowhere has it been suggested for aluminium bronzes that the presence of a small proportion of essentially stable beta phase would give rise to cracking troubles.

The adverse comments about low weld strengths and about the use of sub-standard materials appear to stem from the fact that our correspondents have mis-read the heading of Table IX (not Table II) which refers to butt welds in alloy *D* plate made with various fillers. Nevertheless, the values of tensile strengths quoted for Superston 40 will be of interest, particularly the rather marked differences between the metal-arc and inert-gas metal-arc welds.

Lithium in Aluminium Bronzes

We were aware of the conclusions in the B.N.F.M.R.A. Report RRA.877. However, in the 'Discussion of Results' paragraph of that report, due weight was given to the possibility that the cracking encountered was connected with boundary oxide inclusions arising from the flux coating of the electrodes. We thought it worthwhile, therefore, to examine the effect of lithium on the cracking tendencies of aluminium bronze when inert-gas arc welding methods were used.

We must emphasize that only the Houldcroft hot-cracking tests were carried out, results of which showed, perhaps surprisingly, that the presence of lithium reduces the slight super-solidus cracking tendency of the alloys. No welding trials with lithium-bearing filler rods were made, but they would, in our opinion, be worthwhile, particularly as sub-solidus cracking in aluminium bronze might well be related to the influence of small amounts of bismuth and lead; and the B.N.F.M.R.A. work has shown quite definitely that the embrittling effects of these elements in the mid-temperature range is reduced in the alpha aluminium bronzes by the addition of lithium.

Constitutional Matters

In reporting the work aimed at exploring possible reasons for weld root embrittlement we have perhaps not emphasized sufficiently that heat-treatment and bend tests were carried out only on autogenous alloy *D* welds, principally because this feature was reported to occur only in alpha alloys. There is therefore no possibility of γ_2 phase dissolved during heating of the welds (if present) reforming on cooling, for this phase is unstable in the alpha composition range. We are well aware of course that the distribution of phases is often more significant than the amount present, and for this reason we gave very careful consideration to the theory that γ_2 grain-boundary films were responsible for weld root embrittlement (*see* page 220).

In regard to the proportion of γ_2 which could arise in welds in alpha alloys, our quoted figure of approximately $1\frac{1}{2}$% of beta retained at the solidus, was derived from the equilibrium diagram from which, contrary to the opinion of our correspondents, it can be deduced. The form of the high temperature equilibrium indicates that if beta is to form under conditions of rapid cooling then, although the amount of the phase cannot be predicted, it must have the composition given by the point *D* in our Fig. 6; *i.e.*, 9·5% aluminium. On cooling to room temperature and reheating below 575°C. the beta phase will transform to alpha and γ_2, the proportions being established by the lever rule applied to the $\alpha+\gamma_2$ phase field. The composition limits of this field at 565°C., according to Raynor's diagram[4] are 9·4% Al and 15·6% Al respectively. The proportion of γ_2 is given therefore by $\frac{0{\cdot}1\times 100}{15{\cdot}6-9{\cdot}4}=1{\cdot}6\%$ approx.

It is on this argument that our comment concerning alteration of the equilibrium diagram was based. Thus, although alteration of the point *D* to a value lower than 9·4% Al (say 9·3% Al) would probably increase the amount of beta phase retained under rapid cooling conditions, it could not contain more than 9·3% Al, so that on cooling and reheating the beta phase would transform to alpha only; γ_2 being unable to form at this concentration of aluminium. We must emphasize that our remarks were academic and prefaced with the qualifying phrase "*If* γ_2 were responsible . . ." We do not subscribe to this theory.

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Effect of Diffusible Hydrogen on the Mechanical Properties of Weld Metal

By P. D. Blake, M.A.

SYNOPSIS

THE paper describes the results of some experiments in which the amount of diffusible hydrogen retained in all-weld-metal test pieces, at the time of testing, was varied by means of special machining techniques, and by giving the test pieces heat treatments at 150°C. for various periods of time to remove part or all of the diffusible hydrogen. Diffusible hydrogen was found to have an important effect upon the ductility, and in general a very slight effect upon the impact value.

ALTHOUGH much work has been done to investigate the effect of hydrogen upon the mechanical properties of weld metal,[1,2,3,4,5,6,7] the hydrogen content of the samples has only infrequently been accurately measured; it has often been assumed to vary with heat-treatment, and in some instances the properties of basic and cellulosic electrode deposits have been compared and the differences related to the hydrogen content, the effects of oxygen and composition being neglected.

In the present work, the hydrogen introduced into all-weld test pieces during welding has been retained to various degrees, and the actual hydrogen content of the specimens at fracture has been measured accurately, immediately after fracture, in a vacuum heating apparatus, as previously described by the author.[8,9] To retain, as far as practicable, the hydrogen present at the time of fracture, the specimens were immersed in freezing acetone immediately after testing, and samples suitable for the vacuum heating apparatus were machined under a spray of liquid carbon dioxide.

EXPERIMENTAL PROCEDURE AND RESULTS

The weld metals selected for investigation were those deposited by electrodes of BS.1719:1951* Classes 1, 2, 3, 4, 5, and 6, which are mainly used for welding mild steel. The test pieces were prepared in accordance with Appendix C of BS.639:1952 for all-weld tests, using 6 s.w.g. electrodes throughout, except that:

(*a*) The overall length of the butt was made 21 in., instead of 7 in. as in the specification, so that three virtually identical all-weld Izod or tensile specimens could be machined from the one weld

(*b*) The welds were water quenched from 100°C., so as to reduce the loss of hydrogen during the cooling of the weld, thereby reducing the cooling period by about 1 hr without significantly affecting the mechanical properties

(*c*) No heat treatment at 650°C. was given to any of the specimens because this would have removed most of the hydrogen.

The amount of diffusible hydrogen present in a test piece was adjusted to three different levels by the following procedure:

(i) Most of the diffusible hydrogen was retained by machining the test piece under a spray of liquid carbon dioxide and storing in solid CO_2 until just before the test

(ii) The specimen was machined by a normal machining procedure and partially degassed by placing it in an oven at 150°C. for 24–48 hr before testing

(iii) The specimen was again normally machined but degassed in an oven at 150°C. for 72–168 hr before testing.

Procedures (i), (ii) and (iii) thus correspond to the maximum, intermediate, and minimum diffusible hydrogen contents respectively.

The tensile and Izod impact tests were carried out in accordance with BS.131, all tests being made in a room whose temperature was controlled at 18°C.

It was realized that any ageing which took place during the periods of soaking at 150°C. would obscure the change in mechanical properties because of the removal of hydrogen; nevertheless, some information on the effect of hydrogen would be obtained, especially where there was a striking improvement in some mechanical property such as ductility, from the diffusion of hydrogen out of the specimen.

A few Izod specimens were also aged at room temperature for one week, and were then cathodically charged with hydrogen, using 5% sulphuric acid as the electrolyte.

Immediately after fracture and measurement, all test pieces were placed in solid CO_2 (at about −78°C.) and specimens were then machined from them under liquid CO_2. It was considered that this procedure would retain most of the hydrogen present in the test specimens at the time of the test. However, it has been accepted as inevitable that some hydrogen may be lost during straining and more particularly at fracture. To minimize this, the fractured ends were always machined off for about ¼ in., before turning the specimen for hydrogen determination.

After machining, the specimens were inserted in solid CO_2, and were then transferred to the vacuum

* Tables I and II show the nearest equivalent A.W.S. Classes.

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heating apparatus to determine their total hydrogen content (at 625°C.) in one step, as described in a previous paper.[8] The hydrogen content thus measured is the actual hydrogen content of the weld metal test pieces just after fracture. A number of Izod and tensile test pieces were placed under mercury immediately after fracture and were found on average to evolve hydrogen at the very slow rate of 0·005 ml/hr. For a 2-hr. period between fracture and insertion in the hydrogen apparatus, this represents a loss of about 0·1 ml of hydrogen, even if the specimen were left at room temperature for that time. This evidence was taken to justify the assumption that only a negligible amount of hydrogen was lost during the time between fracture and measurement.

Table I shows the tensile results and corresponding hydrogen figures for all-weld-metal specimens deposited by electrodes of BS.1719: 1951, Classes 1 to 6, and also by an automatic electrode. Table II deals similarly with the Izod figures. The tables also show the nearest American and British equivalent welding electrode classes.

DISCUSSION

It can be seen from Table I that the removal of the diffusible hydrogen does not appear to have any large effect upon the nominal ultimate tensile strength or yield point of the specimens at room temperature. The true breaking stress at fracture tends to increase as the diffusible hydrogen content decreases, although there are exceptions and the effect is not a proportional one. Some of the anomalies, especially in regard to the 168-hr degassing treatment, may to some extent be attributable to ageing; *e.g.*, precipitation of Fe_4N leads to a reduction in tensile strength because it precipitates in relatively thin plates of large cross-sectional area with a reduction in the amount of nitrogen in solid solution to the equilibrium quantity. However, this effect should not be very marked until an ageing temperature of 180–200°C., maintained for a period of 18–26 days, is reached.[10] Schofield[10] aged mild steel for 9 days at 150°C. without nitride precipitation occurring. Moreover, Table I shows that no really significant change in the nominal ultimate tensile strength occurs, even after 163 hr ageing at 150°C., so it is thought that ageing effects are probably of a minor nature. There was no evidence of nitride precipitation to be seen by ordinary microscopical methods, although the possibility of sub-microscopical precipitation cannot be entirely ruled out.

Table I also shows that there is a tendency for the percentage elongation and reduction in area to increase, sometimes markedly, with decrease in the diffusible hydrogen content. The two properties do not vary consistently however, for the percentage elongation and percentage reduction in area do not always increase consistently on prolonged ageing at 150°C. This may possibly be attributable to a slight ageing effect owing to carbon or nitrogen overriding the effect of hydrogen removal.

With BS.1719 Class 6 weld metal it is interesting that a small reduction in hydrogen content (of about 1 ml/100 g) should lead to such a relatively large increase in ductility, as is shown by Table I; a similar effect was obtained with cathodically charged specimens, although to a lesser degree.

Table II shows that mostly, except for the automatic and Class I welds, there is a trend towards a slight increase in impact values with decreasing hydrogen content of the weld metal.

The results appear to be in line with much of the existing published literature on steel generally and on mild steel weld metal.

Table I

Effect of Hydrogen on Tensile Properties of Weld Metal at 18°C. (64·4°F.)

Electrode Type		*Yield Point, tons/sq.in.*	*Nominal U.T.S., tons/sq.in.*	*Breaking Strength, tons/sq.in.*	*Elong. on 1·5 in.,%*	*Red. in Area,%*	*Time at 150°C. (302°F.) hr*	*Hydrogen Content*	
BS.1719 Class	*Nearest A.W.S. Class*							*Total ml/100 g*	*Diffusible ml/100 g*
Automatic		27·8	32·1		28·0	52	0	2·4	1·5
		27·6	31·3		34·7	68	24	1·9	1·0
		27·6	32·1		34·0	70	72	0·9	0·0
Class 1	E.6010	31·7	34·2	40·0	18·7	27	0	9·7	5·3
(E.116P)	E.6011	31·7	33·6	68·7	32·0	66	41	7·1	2·7
		32·0	33·8	51·8	27·3	53	90	4·4	0·0
Class 2	E.6012	32·9	34·3	49·8	26·7	45	0	12·8	6·9
(E.219)		33·4	35·2	67·3	26·0	61	40	8·1	2·2
		32·6	34·7	47·6	28·0	62	163	5·9	0·0
Class 3	E.6013	34·2	36·3	52·0	24·7	34	0	13·0	6·6
(E.319)		31·5	33·1	57·9	29·3	57	40	10·0	3·6
		32·2	34·0	63·4	33·3	62	162	6·4	0·0
Class 4	E.6030	28·2	29·7	52·8	30·0	53	0	16·7	5·4
(E.439)		29·7	29·9	61·1	34·0	61	96	11·5	0·2
		27·8	29·0	62·6	36·0	66	144	11·3	0·0
Class 5	E.6020	24·3	27·0	52·4	31·3	61	0	7·8	2·8
(E.529)		25·1	26·2	50·0	33·3	61	24	6·8	1·8
		23·5	26·0	49·4	30·7	60	45	5·0	0·0
Class 6	E.6015	34·3	35·7	58·4	24·7	53	0	1·8	1·3
(E.619)		33·1	36·6	79·8	28·7	72	2	0·8	0·3
		35·0	37·7	78·5	30·7	70	64	0·5	0·0

Table II

Effect of Hydrogen on Impact Properties of Weld Metal at 18°C. (64·4°F.)

Electrode Type		*Izod Impact Value, ft.lb*				*Charpy Impact Value, ft.lb*	*Character of Fracture*	*Time at 150°C. (302°F.) hr*	*Hydrogen Content*	
BS.1719	*Nearest A.W.S.*	*Position in Weld*							*Total*	*Diffusible*
Class	*Class*	*Top*	*Side*	*Bottom*	*Mean*				*ml/100 g*	
Class 1	E.6010	—	—	—	—	86	Crystalline	0	14·0	3·3
(E.116P)	E.6011	—	—	—	—	82	98% crystalline	20	10·7	0·0
Class 1	E.6010	78·0	74·0	75·5	75·5		Fibrous	0	15·0	7·8
(E.116P)	E.6011	74·5	81·0	81·5	79·0		„ (gas pockets)	24	10·4	3·2
		77·0	78·5	79·0	78·2		„	72	7·2	0·0
Class 2	E.6012	59·0	63·0	61·0	61·0		„	0	11·3	5·0
(E.219)		65·5	58·5	63·5	62·5		„	65	6·8	0·5
		64·5	66·5	66·5	65·66		„	144	6·3	0·0
Class 3	E.6013	64·0	68·0	65·5	65·8		Small crystalline	0	10·1	3·3
(E.319)		62·0	65·0	62·5	63·2		areas	4	9·1	2·2
		69·0	65·5	65·0	66·5		Sound	144	6·8	0·0
Class 4	E.6030	63·0	62·0	64·5	63·2		Small Crystalline	0	18·0	8·3
(E.439)		58·0	66·0	67·5	63·8		areas	24	11·6	1·9
		63·0	65·0	66·0	64·7			120	9·7	0·0
Class 5	E.6020	40·0	41·0	36·5	39·2		30% crystalline	0	8·7	1·2
(E.529)		43·0	39·5	48·0	43·5			22½	7·5	0·0
Class 6	E.6015	54·0	60·5	73·0	62·50		50% crystalline	0	1·64	0·84
(E.619)		86·5	97·0	93·0	92·2		25% crystalline	24	1·1	0·3
		74·0	84·0	86·0	81·3			168	0·8	0·0
Class 6	E.6015	41·0	59·0	63·0	54·3			Cathodically	2·0	1·5
(E.619)		64·5	52·0	53·0	56·5		25% crystalline	charged	1·1	0·6
		65·0	73·0	80·0	72·7				0·5	0·0

CONCLUSIONS

The experimental work reported indicates the following trends:

(1) Increasing diffusible hydrogen in mild steel weld metal leads to decreasing ductility values; in some instances this decrease is very marked whilst in others it is slight. This is qualitatively in agreement with some work by Flanigan,[11] although in earlier work[5] hydrogen did not appear to affect ductility in weld metal.

(2) Increasing hydrogen contents in mild steel weld metal tend to be accompanied by a corresponding decrease in the true tensile breaking stress at fracture.

(3) Hydrogen in the quantities present in these tests is without any really consistent effect upon the nominal ultimate tensile stress or the yield point at 18°C. Since it is known[12,13] that a high enough concentration of hydrogen, cathodically charged, can eliminate the yield point at room temperature, this suggests that there is a certain minimum concentration required for this effect. However, hydrogen concentrations were not actually measured directly in the previous work.[12,13]

(4) Increasing diffusible hydrogen may have a slight effect in reducing the impact value of mild steel weld metal, but, in general, at these high strain rates, the effect of hydrogen is minimized; this is a confirmation of the findings of Schaeffler, Campbell, and Thielsch.[7]

In general, the effects of diffusible hydrogen upon the mechanical properties of mild steel weld metal are essentially similar to its effects upon wrought steel, but owing to the microstructural and other variations encountered in welds, there is less consistency.

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B.W.R.A. REPORT

Strength of Metal-Arc Welds in HP.30 Aluminium Alloy

EFFECT OF POROSITY AND WELD SHAPE

By D. F. Adams, A.I.M.

PREVIOUS work[1] has shown that the general level of weld quality obtained in joints in aluminium alloy made with commercial metal-arc electrodes can be extremely low, and that even under controlled laboratory conditions unsoundness from gas porosity is normally encountered.

This unsoundness is introduced almost entirely by hydrogen derived from the electrode, and any major improvement in weld quality must depend largely on the extent to which the sources of hydrogen can be eliminated. Much has been said of the role played by the flux-coated electrode in the production of porosity, but little information is available on the effect of porosity on weld metal strength.

The investigation reported was an attempt to supply such information and to establish a quantitative relationship between porosity and weld metal strength of metal-arc welds in HP.30 alloy.

SCOPE OF INVESTIGATION

In the present investigation particular emphasis has been placed on the 'double current' deep-penetration technique. Test panels were made by several member firms of the Association, using their own electrodes so as to obtain variations in weld quality. Standard test panels were also prepared, using the self-adjusting arc process to provide weld metal virtually free from porosity, thus indicating the optimum properties attainable.

Most of the tests were concerned with metal-arc double strap fillet welds in the as-welded condition. A limited number of butt welds were also made to provide information on the tensile strength of weld metal at high dilutions (*i.e.*, with a large admixture of parent material).

It would have been desirable to include both as-welded and post-weld heat-treated butt weld samples in the tests, but since not all the test panels sent to manufacturers were returned, the investigation had to be limited to post-weld heat-treated joints with reinforcement and underbead removed. This ensured that failure always occurred in the weld so that the effect of porosity of varying severity could be assessed.

Report LM.1/59/58 of the British Welding Research Association, issued to members in July 1958.
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SYNOPSIS

TENSILE tests have been made on metal-arc butt and fillet welded joints in HP.30 aluminium alloy to determine the effect of porosity on weld-metal strength. Joints made with the self-adjusting arc process were used as comparative standards. The degree of porosity was measured from radiographs.

The results, though limited, indicate that fillet welded joints have from one-third to two-thirds the strength of equivalent joints made with the self-adjusting arc process, but that porosity has less influence on the strength of butt welds than the presence of other defects such as flux inclusions and cracks.

MATERIALS

The plate material was to specification HP.30 WP, the compositions being:

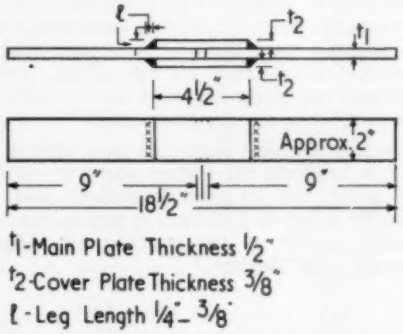
	Cu, %	Mg, %	Si, %	Mn, %	Fe, %
½ in. thick	0·025	0·79	1·05	0·68	0·25
⅜ in. thick	0·030	0·66	1·09	0·79	0·26

As the welding was done by member firms the actual core wire compositions were not available, but standard NG.2 (Al–10% Si) and NG.21 (Al–5% Si) commercial electrodes were used, and the $\frac{1}{16}$ in. dia. wire used for the standard test panels was also to the same specifications.

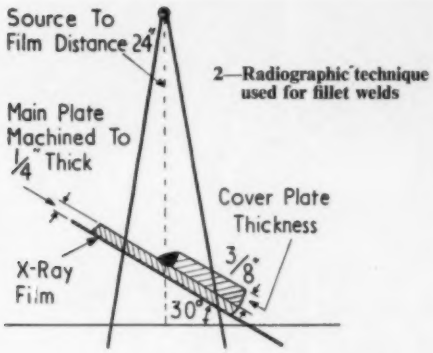
EXPERIMENTAL PROCEDURE

Fillet welds

The relative proportions of the weld and plate materials, shown in Fig. 1, were selected so that the



1—Dimensions of transverse tensile test specimens for double strap fillet welds



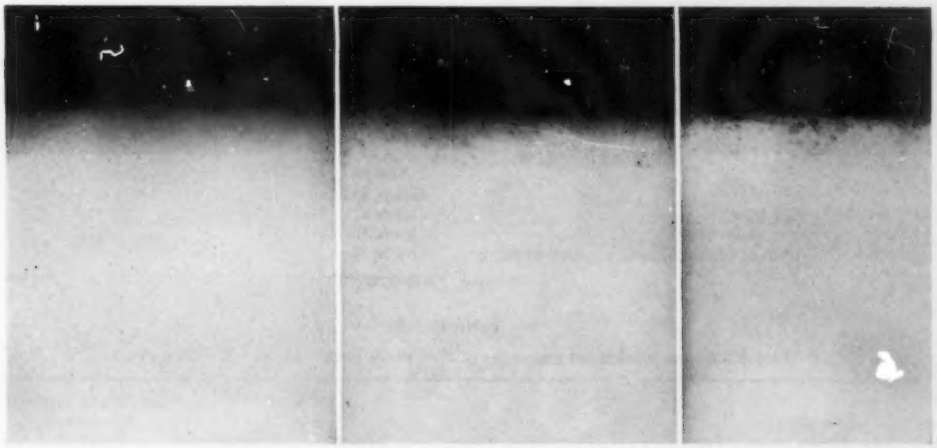
2—Radiographic technique used for fillet welds

average tensile stress in the plate did not exceed the shear stresses on the effective throat area of the welds. A margin of safety against plate failure was therefore ensured. Approximately eight tensile test pieces were machined from each panel, all weld craters being discarded.

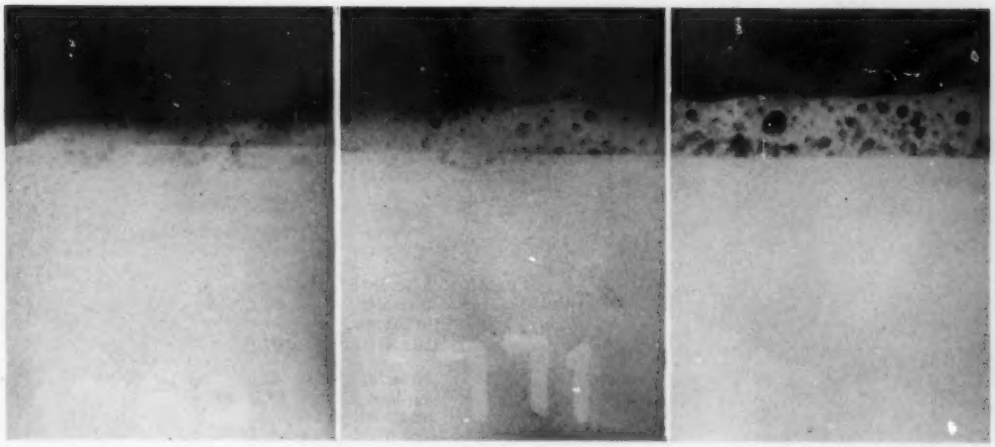
All double strap fillet weld test panels were made with 6 s.w.g. NG.21 or NG.2 electrodes at approx. 290–300 amp, with suitable welding conditions to give a fillet leg length of about $\frac{1}{4}$ in. Electrode changeover points were arranged to coincide on each of the four successive welds so as to reduce to a minimum the quantity of suspect material in each panel. The self-adjusting arc standard pieces were made at 250 amp and at a welding speed of 12 in./min.

Radiography was used throughout as a method of test selection and porosity classification. The double strap fillet weld panels were radiographed before the machining of tensile tests and all unsatisfactory material was discarded. The resulting radiographs, although suitable for general inspection of weld quality, are not suitable for reproduction in this report. Radiographs of single welds from each panel were therefore prepared by the technique shown in Fig. 2.

They were graded independently by five investigators, according to the severity of porosity present, and are presented in order of increasing degree of unsoundness in Figs. 3 and 4. The order of mechanical

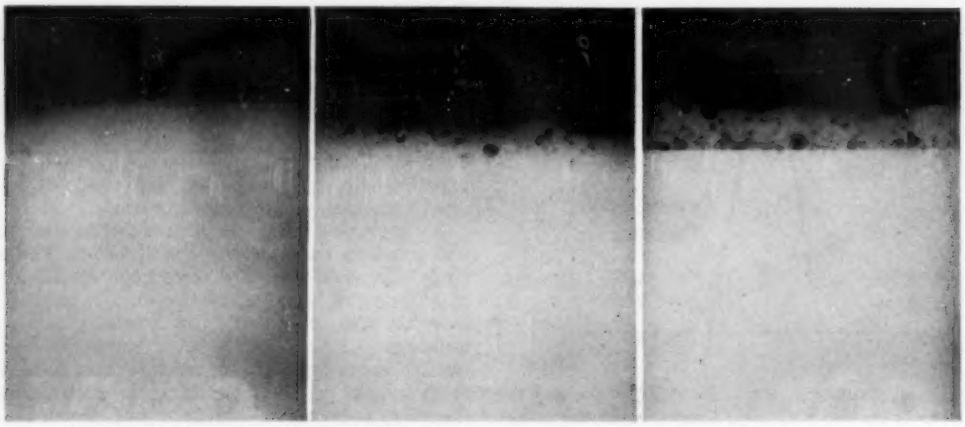


(*a*) 1251 (11·3 tons/sq.in.) (*b*) 1770 (7·8 tons/sq.in.) (*c*) 1773 (7·3 tons/sq.in.)



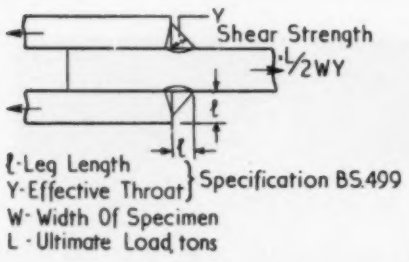
(*d*) 1769 (7·3 tons/sq.in.) (*e*) 1771 (7·1 tons/sq.in.) (*f*) 1808 (4·0 tons/sq.in.)

3—Effect of porosity on shear strength of fillet welds (NG.21 electrodes)



(*a*) 1252 (11·80 tons/sq.in.) (*b*) 1772 (8·1 tons/sq.in.) (*c*) 1809 (5·9 tons/sq.in.)

4—Effect of porosity on shear strength of fillet welds (NG.2 electrodes)



5—Dimensions for calculation of ultimate shear strength of fillet welds

Table I

Classification of porosity

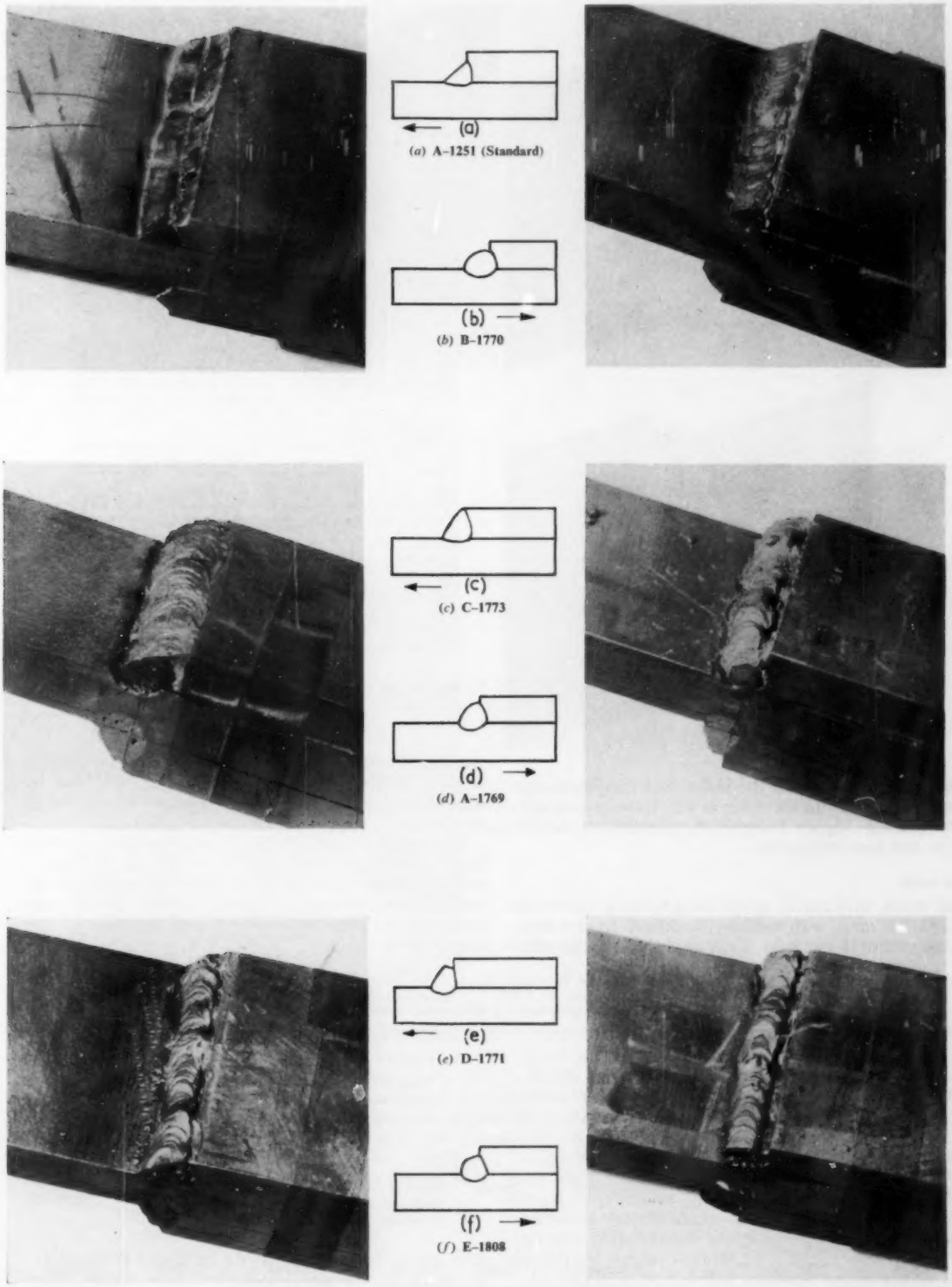
Extent	*Number of pores per square inch of radiograph*
Extensive	$>160\ t$
Scattered	$40\ t$–$160\ t$
Sparse	$<40\ t$
Nature	*Approx. average dia., in.*
Grade D	$\frac{1}{8}$ or more
Grade C	$\frac{1}{16}$
Grade B	$\frac{1}{32}$
Grade A	$\frac{1}{64}$

Table II

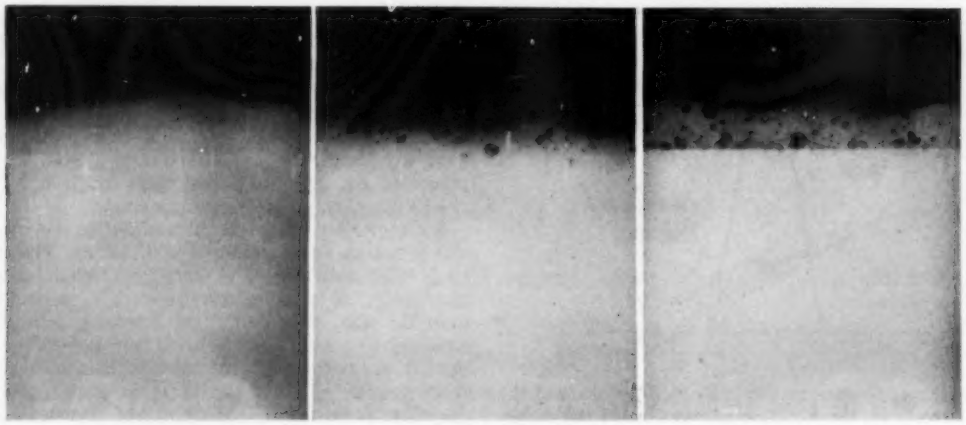
Weld details and mechanical properties of fillet welds made with NG.21 electrodes

Manufacturer and Test No.	*Effective Throat Thickness, in.*	*Leg Length, in.*	*Weld Shape*	*Uniformity*	*General Appearance of Weld*	*Classification of Porosity*	*Ultimate Shear Strength of Effective Throat Thickness, *tons/sq.in.*	*Figure No.*
A–1251 (Standard)	0·24	$\frac{1}{16}$	Normal (mitre)	Good		Clean	11·30	3*a* and 6*a*
B–1770	0·27	$\frac{3}{8}$	Irregular tending to convex	Fair	Slightly undercut in places	Extensive grade B	7·80	3*b* and 6*c*
C–1773	0·23	$\frac{3}{16}$	Convex and unequal leg length	Poor–Fair	Slightly undercut in places	Extensive grade B	7·30	3*c* and 6*e*
A–1769	0·25	$\frac{7}{32}$	Convex	Fair	Slightly undercut in places	Extensive grade B	7·30	3*d* and 6*b*
D–1771	0·27	$\frac{1}{4}$	Rather convex	Fair	Severely undercut in places	Scattered grade C and extensive grade B	7·10	3*e* and 6*d*
E–1808	0·26	$\frac{1}{4}$	Excessive convexity	Poor	Holes in surface undercut and overlap	Extensive grade C and sparse grade D	4·00†	3*f* and 6*f*

* Average of eight test samples. † Poor weld shape.

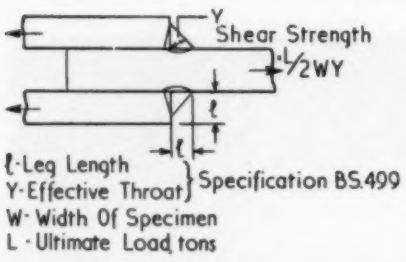


6—Appearance of double strap fillet welds made with NG.21 electrodes



(*a*) 1252 (11·80 tons/sq.in.) (*b*) 1772 (8·1 tons/sq.in.) (*c*) 1809 (5·9 tons/sq.in.)

4—Effect of porosity on shear strength of fillet welds (NG.2 electrodes)



5—Dimensions for calculation of ultimate shear strength of fillet welds

Table I

Classification of porosity

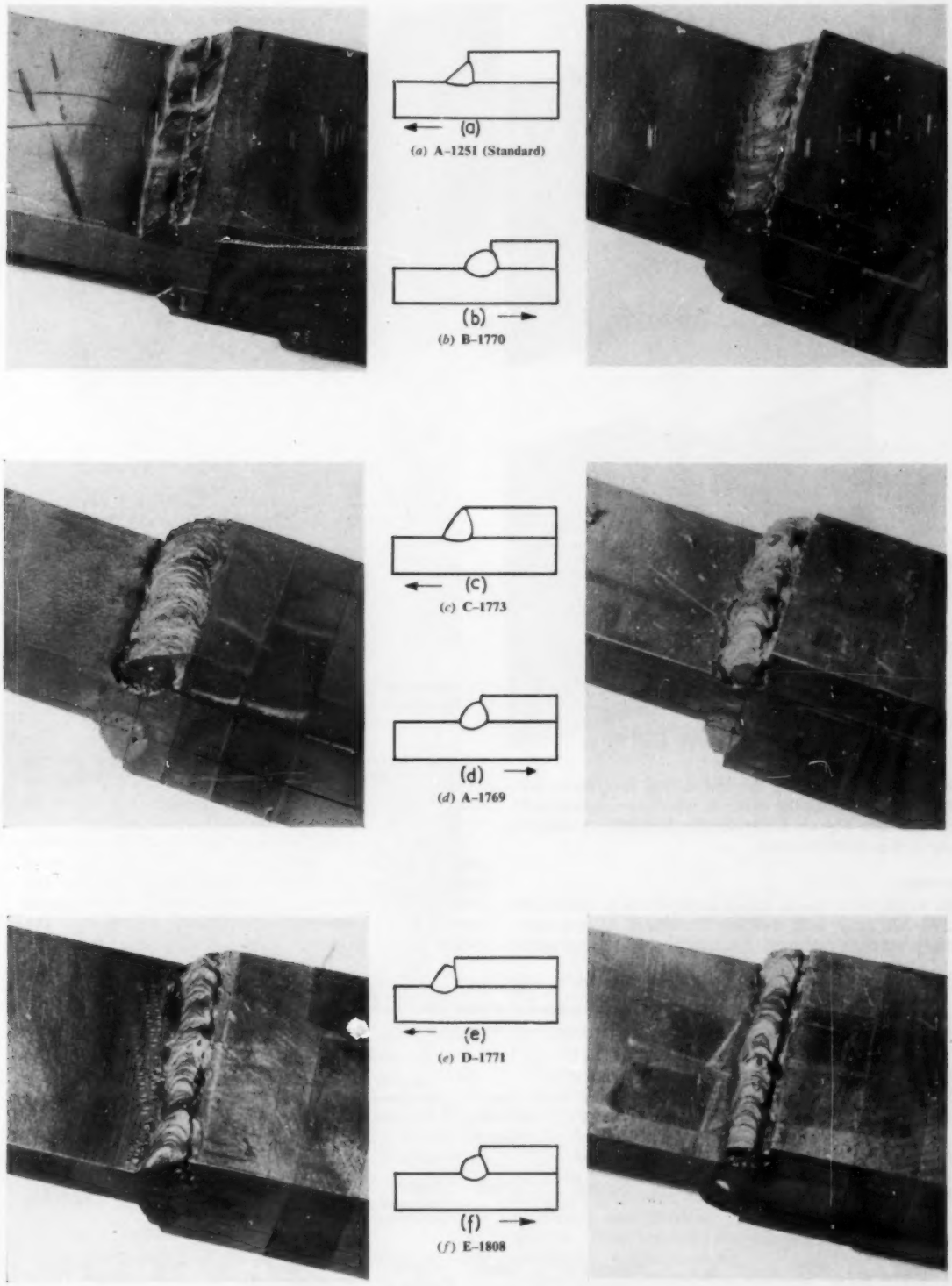
Extent	*Number of pores per square inch of radiograph*
Extensive	$>160\,t$
Scattered	$40\,t$–$160\,t$
Sparse	$<40\,t$
Nature	*Approx. average dia., in.*
Grade D	$\frac{1}{4}$ or more
Grade C	$\frac{1}{8}$
Grade B	$\frac{1}{16}$
Grade A	$\frac{1}{64}$

Table II

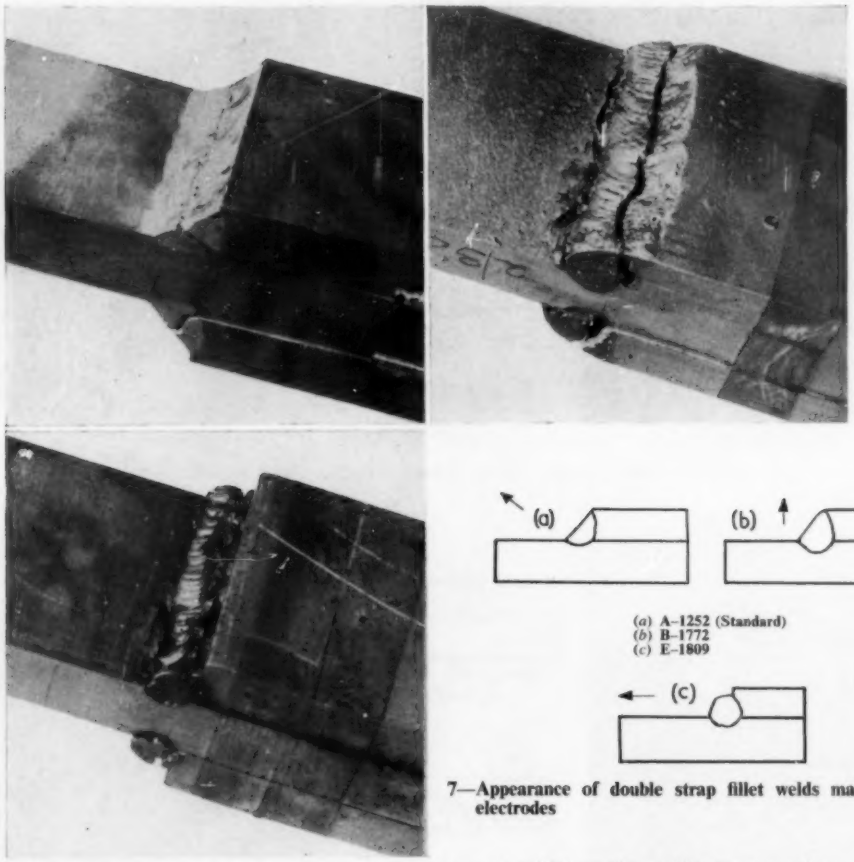
Weld details and mechanical properties of fillet welds made with NG.21 electrodes

Manufacturer and Test No.	*Effective Throat Thickness, in.*	*Leg Length, in.*	*Weld Shape*	*Uniformity*	*General Appearance of Weld*	*Classification of Porosity*	*Ultimate Shear Strength of Effective Throat Thickness, *tons/sq.in.*	*Figure No.*
A–1251 (Standard)	0·24	$\frac{5}{16}$	Normal (mitre)	Good		Clean	11·30	3*a* and 6*a*
B–1770	0·27	$\frac{3}{8}$	Irregular tending to convex	Fair	Slightly undercut in places	Extensive grade B	7·80	3*b* and 6*c*
C–1773	0·23	$\frac{7}{16}$	Convex and unequal leg length	Poor–Fair	Slightly undercut in places	Extensive grade B	7·30	3*c* and 6*e*
A–1769	0·25	$\frac{7}{32}$	Convex	Fair	Slightly undercut in places	Extensive grade B	7·30	3*d* and 6*b*
D–1771	0·27	$\frac{1}{4}$	Rather convex	Fair	Severely undercut in places	Scattered grade C and extensive grade B	7·10	3*e* and 6*d*
E–1808	0·26	$\frac{1}{4}$	Excessive convexity	Poor	Holes in surface undercut and overlap	Extensive grade C and sparse grade D	4·00†	3*f* and 6*f*

* Average of eight test samples. † Poor weld shape.



6—Appearance of double strap fillet welds made with NG.21 electrodes



(*a*) A–1252 (Standard)
(*b*) B–1772
(*c*) E–1809

7—Appearance of double strap fillet welds made with NG.2 electrodes

properties obtained on the individual specimens corresponded well with the order in which the radiographs were graded. Figure 5 shows the dimensions used in shear test determinations.

Butt welds

Butt welds were made, again using 6 s.w.g. electrodes at 290–300 amp, with welding conditions to give satisfactory welds in one pass. Each weld was radiographed on completion of machining operations and given a solution treatment for 50 min at 520°C., followed by quenching in cold water and age hardening for 10 hr at 170°C.

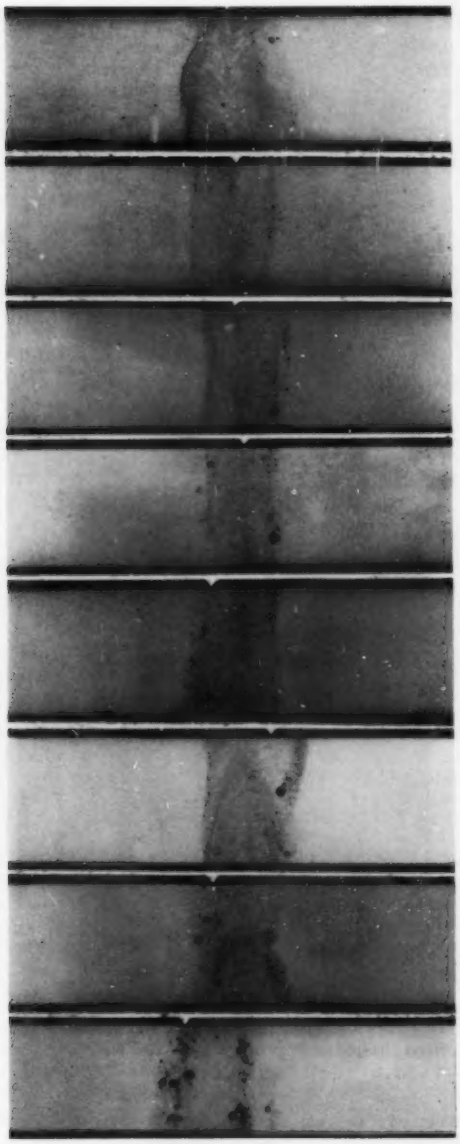
Porosity of uniform size and distribution lends itself readily to classification by the microscopical method,[2] but this method is not recommended for the examination of metal-arc welds because of the great variation in pore size experienced throughout the length of the weld.

Table III

Weld details and mechanical properties of fillet welds made with NG.2 electrodes

Manufacturer and Test No.	*Effective Throat Thickness, in.*	*Leg Length, in.*	*Weld Shape*	*Uniformity*	*General Appearance of Weld*	*Classification of Porosity*	*Ultimate Shear Strength of Effective Throat Thickness, *tons/sq.in.*	*Figure No.*
A–1252 (Standard)	0·24	$\frac{1}{4}$	Normal (mitre)	Good		Clean	11·80	4*a* and 7*a*
B–1772	0·29	$\frac{3}{8}$	Normal	Good	Slightly undercut in places	Sparse grade C and extensive grade B	8·10	5*b* and 7*b*
E–1809	0·25	$\frac{7}{32}$	Excessively convex	Good	Slightly undercut in places	Scattered grade C and extensive grade B	5·90	4*c* and 7*c*

* Average of eight test samples.



(*a*) **Extensive, Grade A, 20 tons/sq.in.**

(*b*) **Extensive, Grade A, 19·5 tons/sq.in.**

(*c*) **Extensive, Grade A and sparse Grade B, 18·8 tons/sq.in.**

(*d*) **Extensive, Grade A and scattered Grade B, 18·6 tons/sq.in.**

(*e*) **Extensive, Grade A and scattered Grade B, 17 tons/sq.in.**

(*f*) **Extensive, Grade A and scattered Grade B, 16·9 tons/sq.in.**

(*g*) **Extensive, Grades A and B, 15 tons/sq.in.**

(*h*) **Extensive, Grade B, 15 tons/sq.in.**

8—Effect of porosity on tensile strength of butt welds made with NG.21 electrodes. (Position of fracture indicated by nick)

In the method employed in this investigation, classification was carried out on the radiograph, and both the extent and nature of the porosity are described. Table I shows the arbitrary scale chosen for this purpose, the value of t being the parent metal thickness for butt welds and half the leg length for fillet welds. The relationship between this system of classification and the percentage voids in the welds is shown in Table IV.

DISCUSSION OF RESULTS

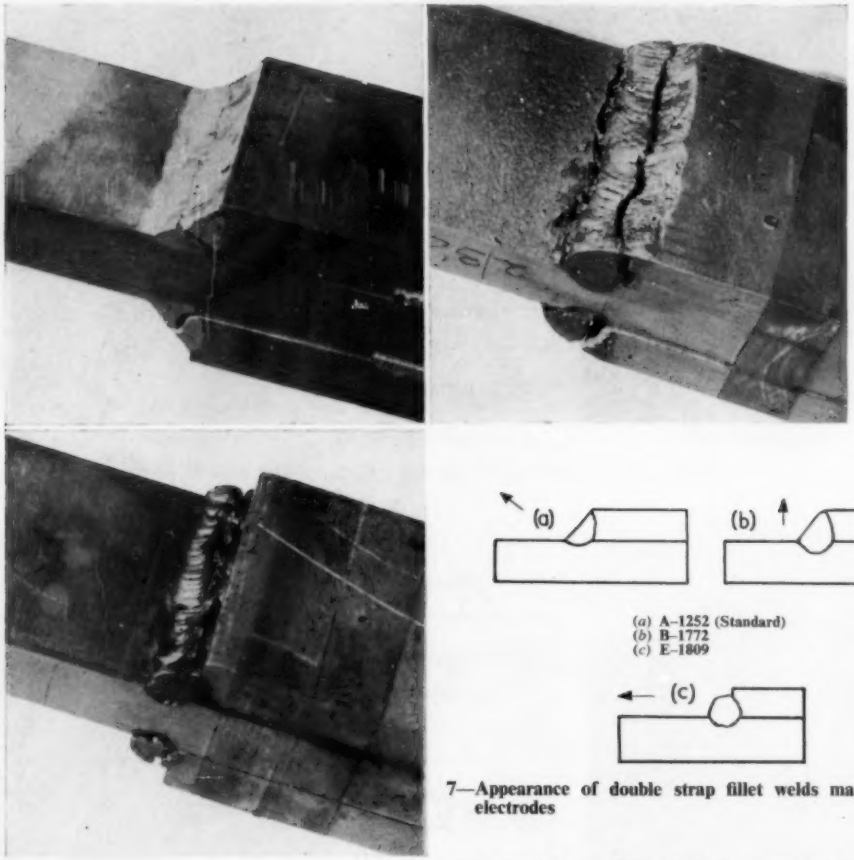
Complete details of the weld examination for fillet welds made with NG.21 electrodes are given in Table II, and with NG.2 electrodes in Table III.

The fractured tensile specimens are illustrated in Figs. 6 and 7 for the two filler alloys NG.21 and NG.2 respectively, with the corresponding radiographs in Figs. 3 and 4.

Results for the butt welded specimens are not given in tabular form but are included in Figs. 8 and 9 for welds made with NG.21 and NG.2 electrodes respectively.

The actual strength values recorded can be used only for comparison and they are not suitable for design purposes for, as already stated, the fillet welded specimens were made to ensure fracture in the welds, and the butt welded samples were post-weld heat-treated for similar reasons.

It is to be expected that unsound welds will be less strong than sound welds, but some idea of the magnitude of the effect of unsoundness is evident from the results recorded. The fillet weld results have been



(*a*) A–1252 (Standard)
(*b*) B–1772
(*c*) E–1809

7—Appearance of double strap fillet welds made with NG.2 electrodes

properties obtained on the individual specimens corresponded well with the order in which the radiographs were graded. Figure 5 shows the dimensions used in shear test determinations.

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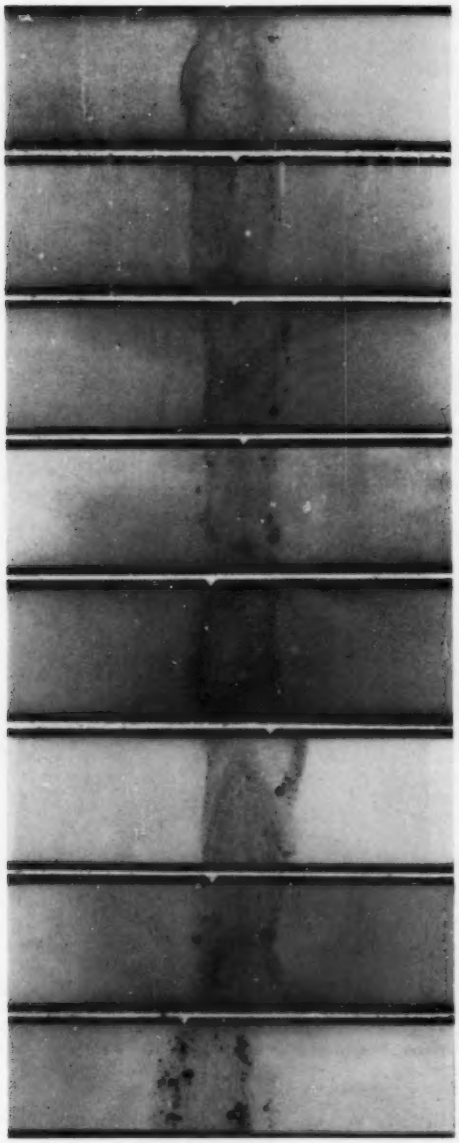
Porosity of uniform size and distribution lends itself readily to classification by the microscopical method,[2] but this method is not recommended for the examination of metal-arc welds because of the great variation in pore size experienced throughout the length of the weld.

Table III

Weld details and mechanical properties of fillet welds made with NG.2 electrodes

Manufacturer and Test No.	*Effective Throat Thickness, in.*	*Leg Length, in.*	*Weld Shape*	*Uniformity*	*General Appearance of Weld*	*Classification of Porosity*	*Ultimate Shear Strength of Effective Throat Thickness, *tons/sq.in.*	*Figure No.*
A–1252 (Standard)	0·24	$\frac{5}{16}$	Normal (mitre)	Good		Clean	11·80	4*a* and 7*a*
B–1772	0·29	$\frac{3}{8}$	Normal	Good	Slightly undercut in places	Sparse grade C and extensive grade B	8·10	5*b* and 7*b*
E–1809	0·25	$\frac{7}{32}$	Excessively convex	Good	Slightly undercut in places	Scattered grade C and extensive grade B	5·90	4*c* and 7*c*

* Average of eight test samples.



(*a*) **Extensive, Grade A, 20 tons/sq.in.**

(*b*) **Extensive, Grade A, 19·5 tons/sq.in.**

(*c*) **Extensive, Grade A and sparse Grade B, 18·8 tons/sq.in.**

(*d*) **Extensive, Grade A and scattered Grade B, 18·6 tons/sq.in.**

(*e*) **Extensive, Grade A and scattered Grade B, 17 tons/sq.in.**

(*f*) **Extensive, Grade A and scattered Grade B, 16·9 tons/sq.in.**

(*g*) **Extensive, Grades A and B, 15 tons/sq.in.**

(*h*) **Extensive, Grade B, 15 tons/sq.in.**

8—Effect of porosity on tensile strength of butt welds made with NG.21 electrodes. (Position of fracture indicated by nick)

In the method employed in this investigation, classification was carried out on the radiograph, and both the extent and nature of the porosity are described. Table I shows the arbitrary scale chosen for this purpose, the value of t being the parent metal thickness for butt welds and half the leg length for fillet welds. The relationship between this system of classification and the percentage voids in the welds is shown in Table IV.

DISCUSSION OF RESULTS

Complete details of the weld examination for fillet welds made with NG.21 electrodes are given in Table II, and with NG.2 electrodes in Table III.

The fractured tensile specimens are illustrated in Figs. 6 and 7 for the two filler alloys NG.21 and NG.2 respectively, with the corresponding radiographs in Figs. 3 and 4.

Results for the butt welded specimens are not given in tabular form but are included in Figs. 8 and 9 for welds made with NG.21 and NG.2 electrodes respectively.

The actual strength values recorded can be used only for comparison and they are not suitable for design purposes for, as already stated, the fillet welded specimens were made to ensure fracture in the welds, and the butt welded samples were post-weld heat-treated for similar reasons.

It is to be expected that unsound welds will be less strong than sound welds, but some idea of the magnitude of the effect of unsoundness is evident from the results recorded. The fillet weld results have been

(*a*) Extensive, Grade A, 19·7 tons/sq.in.

(*b*) Extensive, Grade A, 19·7 tons/sq.in.

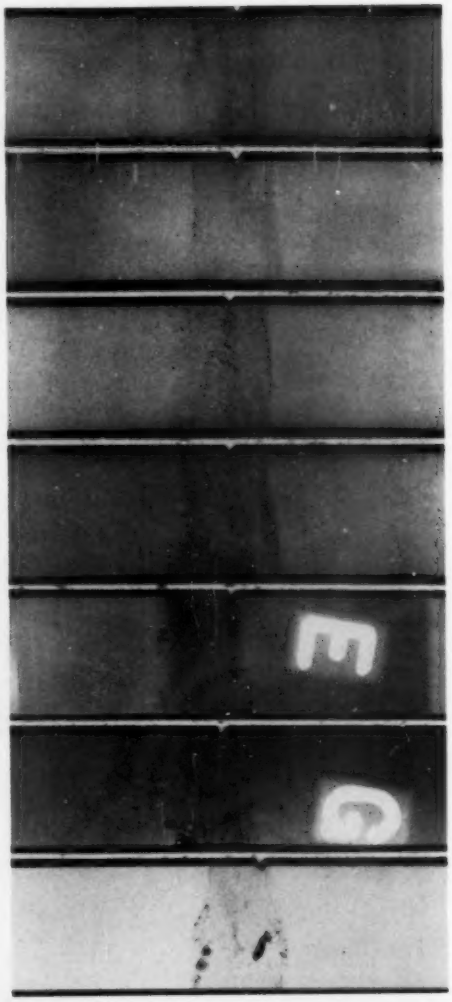
(*c*) Extensive, Grade A, 19·3 tons/sq.in.

(*d*) Extensive, Grade A, 18·8 tons/sq.in.

(*e*) Extensive Grade A and scattered Grade B, 16·2 tons/sq.in.

(*f*) Extensive, Grade B, 15·5 tons/sq.in.

(*g*) Flux inclusion, 15·8 tons/sq.in.



9—Effect of porosity on tensile strength of butt welds made with NG.2 electrodes. (Position of fracture indicated by nick)

influenced to some extent by weld size and shape, but it has not been found possible to correct for this in the presentation of results.

The strength values of 11·3 and 11·8 tons/sq.in. obtained in the 'standard' fillet joints, using the NG.21 and NG.2 filler alloys, are fairly typical of sound welds of good shape. Even the best of the metal-arc fillet welds falls considerably below this standard (8·1 tons/sq.in.) and the worst is only one-third as strong as the self-adjusting arc-welded joint. The properties of joints made with NG.2 (10% Si) filler are slightly higher than those made with NG.21 (5% Si) filler as might be expected from the higher alloying content of the latter material and the absence of age-hardening constituents.

The effect of porosity on the properties of post-weld heat-treated butt welds is again related to the amount of porosity present, and the range of strength is 15–20 tons/sq.in. Isolated pores of the type illustrated in Figs. 8*c* and 8*d* do not have such a serious effect as a concentration of pores along a weld boundary, as shown in Figs 8*e* and 8*f*. Serious porosity, of the

Table IV

Relationship between description of porosity and percentage voids in weld metal

Extent	*Nature (Grade)*	*Approx. % voids*	*Effect on Weld Properties*
Sparse	A	up to 0·01	
Scattered	A	0·01–0·03	
Extensive	A	0·03–0·10	Slight
Sparse	B	up to 0·06	
Scattered	B	0·06–0·25	
Extensive	B	0·25–0·75	Moderate
Sparse	C	up to 0·50	
Scattered	C	0·50–2·00	
Extensive	C	2·00–6·00	
Sparse	D	up to 4·00	Serious
Scattered	D	4·00–16·00	
Extensive	D	—	

extent illustrated in Figs. 8*g* and 8*h*, normally occurs only intermittently in metal-arc butt welds; it may, therefore, be concluded that the porosity usually encountered in such welds, using the high-current technique, will not greatly influence the strength of a joint. The serious effect of flux inclusions is shown in Fig. 9*g*; such defects may well mask the effects of gas porosity.

CONCLUSIONS

It has been extremely difficult to obtain reproducible results with the metal-arc process, even under laboratory conditions; although a considerable number of samples were prepared and tested, the results obtained were extremely limited. It is not possible, therefore, to provide a comprehensive picture of the effect of porosity on the strength of metal-arc welds in HP.30 alloy, but sufficient work has been done to enable certain general conclusions to be reached:

(1) For fillet welds, the quality attainable by the metal-arc process falls much below that attainable by the self-adjusting arc process. According to the severity of the porosity present, the properties of metal-arc welded fillets may vary between one-third and two-thirds of the optimum value of approximately 12 tons/sq.in. obtained in good self-adjusting arc welds.

(2) The effects are similar for both NG.21 and NG.2 electrodes.

(3) In fillet welding, other factors such as poor weld shape have a considerable effect on joint strength and should be taken into consideration.

(4) In butt welds (for which the process is much more suitable) the effect of porosity in the amounts normally encountered is much less serious. Other defects, such as flux inclusions and cracks, will have a much more serious effect.

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1. W. G. HULL and D. F. ADAMS: *Brit. Welding J.*, 1958, vol. 5, pp. 282–290.
2. P. T. HOULDCROFT and A. A. SMITH: *ibid*, 1955, vol. 2, p. 67–74.

SYMPOSIUM ON ALUMINIUM PRESSURE VESSELS

This Symposium, which was in the nature of a fact-finding conference, proved to be an unqualified success, and provided an opportunity of presenting all available data on the subject to a gathering of 450. The titles of the papers have already been given in the *Journal*; they cover a review of existing codes of practice, aluminium materials suitable for pressure vessels, and fabrication and service experience.

Of particular value was the survey of current specifications and codes prepared by Rose and Young, taking into account British, American, and European recommendations.

It was apparent from the paper and the detailed discussion, that a stage has now been reached where either a specific code for aluminium vessels should be drawn up, or provision should be made in BS. 1500 for vessels made from this metal. The authors note the points to be considered in preparing a specification of this type, and consider that the recent proposals of Commission XI of the International Institute of Welding for a "rational design procedure for pressure vessels" might well be incorporated.

In the paper on aluminium alloys, the author provided in one document a complete summary of mechanical properties at room, elevated, and low temperatures, both in respect of wrought and cast materials. Account is taken of the affect of welding, resistance to corrosion, and useful figures are quoted for fatigue and creep. In the discussion on this paper, a plea was made for fatigue values at a lower number of cycles, and for information on the physical properties of aluminium alloys at elevated and low temperatures.

During the tea interval, those present were able to examine the very interesting exhibits and photographs that had been assembled to provide a comprehensive but cramped picture of this field. Several models of pressure vessels were shown, and other items of interest included a heat exchanger, a selection of forged pressure vessels for containing gases, and a wide selection of weld specimens and test pieces in thick aluminium plate. Much interest was aroused by such a weld in 4½ in. aluminium–magnesium alloy, and in radiographs of welds selected to indicate the limited effect of porosity on the strength of aluminium welds.

The evening session evoked greater discussion, and the contributors covered a wide range of topics. It is these papers, on fabrication and service, that are of particular interest to the welding fraternity, and in a characteristic manner, Lancaster gave a full account of his experiences over the years, not only of the techniques for making first-class welds, but of preparing them for welding and testing. The final paper discussed the use of aluminium pressure vessels in various items of chemical plant, particularly for ammonium carbonate, formaldehyde, for absorption towers and for high-pressure gas containers. More recently, the field of low-temperature applications has required the use of aluminium alloy vessels.

In the discussion of this paper, it was particularly interesting to hear Dr. Richard Seligman's account of the very first aluminium pressure vessel made in Britain. He showed two slides illustrating a vessel for beer, made in 1910 from $\frac{3}{16}$ in. pure aluminium, and of a 6 ft diameter vessel working at temperature, welded in 1912. He also gave a most interesting account of working conditions in those days. A speaker from the chemical industry gave an account of his experiences with aluminium pressure vessels, and mentioned several methods of overcoming the problem of binding threads. A speaker from the Netherlands gave an account of welding problems experienced in that country.

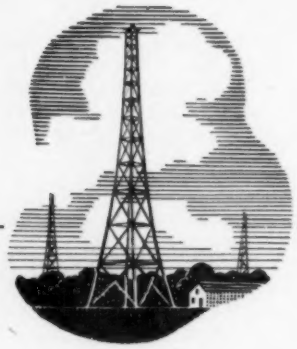
In discussing welding aspects, the high quality of welds made by newly developed techniques for thick plate and for thin sheet was emphasized, and observations were made on the use of high currents and untreated welding wire. A plea was made for information on the welding of wrought material to castings, and details were given of methods to overcome such difficulties as tungsten inclusions, cracks, and porosity.

Throughout the Symposium it was apparent that the teething troubles formerly associated with the fabrication of aluminium vessels and structures to the highest quality have largely been overcome, and that industry now demands the writing up of such procedures into a formal code.

In concluding the proceedings, Professor Hugh Ford, Chairman of the Organizing Committee, emphasized this logical sequel to the Symposium and expressed the satisfaction of the organizers and the Institution with the full attendance, and the enthusiasm that had been shown at the meeting.

N. T. BURGESS

NEWS
and Announcements



News of the Institute and Branches
B.W.R.A. · Other Societies ·
and Industry

INSTITUTE ACTIVITIES

MEETINGS

Hydrogen in Steel

A special joint meeting with the Iron and Steel Institute, to discuss the measurement and effects of hydrogen in mild steel weld metal, is to be held on **Wednesday, 10th December.** The meeting will commence at 2.30 p.m. and will be held in the Weir Lecture Hall of the Institution of Naval Architects, 10 Upper Belgrave Street, London, S.W.1 (not at the offices of the Iron and Steel Institute as announced on the Programme Card distributed to members of the Institute of Welding).

The details of papers to be presented were given in the November issue of the *Journal* (p. 539).

Autumn Meeting 1958

The Autumn Meeting opened as usual with the Annual Dinner at the Park Lane Hotel on the evening of Wednesday, 5th November. Nearly 400 members and their guests attended. The President, Mr. J. Strong, was in the Chair and the principal guests were Mr. W. J. Taylor, C.B.E., D.L., J.P., M.P., Parliamentary Secretary to the Ministry of Supply (replacing the Minister of Supply, who was prevented from coming by urgent public business), Lord Coleraine, and the Bishop of Kensington. Mr. Taylor proposed the Toast of the Institute in a speech stressing its services to technical education; the President responded with a summary survey of the Institute's recent progress. The Toast of the Guests was proposed by the immediate Past President, Sir Charles Lillicrap, and both Lord Coleraine and the Bishop of Kensington responded. Among other guests present were:

Mr. T. E. Potts (Chairman, British Oxygen Gases, Ltd.); Mr. R. Jenkins, J.P. (Chairman, Tank and Industrial Plant Association; Chairman of Council, British Welding Research Association); Mr. James Brown (Chairman, British Constructional Steelwork Association); Mr. J. A. Milne (President, Shipbuilding Conference); Dr. R. Lessing, C.B.E. (a Vice-Chairman, British Chemical Plant Manufacturers' Association); Mr. W. W. Watt, C.B.E. (Chairman, Arc Welding Electrodes Section, B.E.A.M.A.); Mr. John Ryan (President, Institute of Sheet Metal Engineering); Dr. E. G. West (Technical Director, Aluminium Development Association); Mr. E. Seymour-Semper (President, British Acetylene Association); Sir Victor Shepheard, K.C.B. (former Director of Naval Construction, Admiralty); Mr. E. D. E. Andrews (representing Sir Ivan Stedeford, K.B.E., Tube Investments, Ltd.); Mr. A. J. Sims, O.B.E. (Director-General, Ships, Admiralty); and Mr. John Pike (Treasurer, Metal Sprayers' Association).

On the following morning Mr. Strong delivered the Presidential Address, which appears elsewhere in this issue, and then took the Chair at the first session for the presentation and discussion of technical papers.

Mr. Seymour-Semper took the Chair at the second session, and Professor Wesley Austin and Dr. E. G. West presided over the two remaining sessions on the Friday.

The attendance at the technical meetings ranged from 90 to 60, and the discussion was well maintained and occupied the whole of the time available.

Symposium on Aluminium Pressure Vessels

A brief report, by a member attending the Symposium held at the Institution of Mechanical Engineers on 28th October, is given on p. 575.

The full report of the proceedings, including the papers presented for discussion, will be published in due course by the Institution.

It is intended that a summary report will be printed in a later issue of the *Journal*.

SUBSCRIPTIONS

Relief of Income Tax on Subscriptions

The Commissioners of Inland Revenue have approved the Institute of Welding for the purposes of Section 16 of the Finance Act 1958, so that the whole of the Annual Subscription paid by a member, who qualifies for relief under that Section, will be allowable as a deduction from his emoluments assessable to income tax under Schedule E. Beginning with the year ending 5th April,1959, a member who is an office holder or employee is entitled to a deduction from the amount of his emoluments of the whole of his Annual Subscription to the Institute, provided that:

(*a*) The subscription is paid out of the emoluments of his office or employment, and

(*b*) that the activities of the Institute, so far as they are directed to the advancement and spreading of knowledge and the maintenance and improvement of standards of conduct and competence among members, are relevant to the office or employment of the member.

This means that the member must be able to show that the knowledge gained through membership of the Institute affects the performance of his duties in his employment.

A member who pays his own subscription and is therefore entitled to this relief should apply to his tax office as soon as possible for Form P. 358, on which to claim for adjustment of his P.A.Y.E. coding.

APPEAL TO INDUSTRY

The following donations have been received since the publication of the list printed in the September issue of the *Journal* (page 435). Contributors marked with an asterisk have responded to the appeal under other headings.

Donation

£150 The three Welding Sections of the British Electrical and Allied Manufacturers' Association.

Commonwealth Welding Conference Guarantee Fund

The following have given the sums named, which were returnable to them as Guarantors of the Conference.

£19. 18. 2 Firth Vickers Stainless Steels Ltd.; Rolls Royce Ltd.

£10 or under Thos. Bolton & Sons Ltd.; Burnett & Rolfe Ltd.; Foster, Yates & Thom Ltd.; Head, Wrightson & Co. Ltd.; *Metropolitan-Vickers Electrical Co. Ltd.; *Mitchell, Russell & Co. Ltd.; Newton Chambers & Co. Ltd.; *Park Gate Iron & Steel Co. Ltd.; *Woodhall-Duckham Construction Co. Ltd.

Annual Subscriptions

The following have promised or covenanted annual subscriptions of the amounts shown, over a period of years:

£31. 10. 0 a year — *Metropolitan-Vickers Electrical Co. Ltd.

£21 a year — *Woodall-Duckham Construction Co. Ltd.

The total sum received or promised to date is £9,151, made up of £5,910 from donations, £864 transferred from the Guarantee Fund for the Commonwealth Welding Conference, and £2,377 from the value of annual subscriptions over seven years.

PUBLICATIONS

Index to Transactions and Welding Research, 1938–1953

The Institute has recently published a comprehensive name and subject index to the 16 volumes of its *Transactions*, which appeared between 1938 and 1953, and to the 7 volumes of *Welding Research*, published as a supplement to the *Transactions* by the British Welding Research Association between 1947 and 1953. These two publications contained the most important and significant results of welding research undertaken in Great Britain during these years, and the Index is therefore a means of reference to a large body of material of lasting technical value. Copies of the Index, produced by the offset litho process and comprising 92 pages, can be obtained from the Institute of Welding, 54 Princes Gate, London, S.W.7, price 25*s*. plus 1*s*. postage (20*s*. plus 1*s*. for members of the Institute and B.W.R.A.).

NEWS OF MEMBERS

A. G. Thompson, industrial engineering consultant, has been awarded an Institution of Production Engineers Medal for the best paper presented in 1956/57 by a non-member.

J. A. Ross has retired from his appointment as mechanical and electrical engineer at the Middlesbrough and Hartlepools Docks.

R. B. Whalley has been appointed Managing Director of Inspection Services Ltd., a new firm of welding consultants, specializing in welding inspection. He was previously chief welding engineer for Metal and Pipeline Endurance Ltd.

R. M Gooderham, Director of the Canadian Welding Bureau, who sustained serious injuries while hunting on 1st November, is now reported to be out of danger.

The Council regret to record the deaths of **N. P. M. Hill** (Associate 1945, Birmingham Branch), and **Thomas Edward Lindsay**, of Vulcan Welding Products Ltd., Gateshead (Member).

BRANCH NEWS

MEETING REPORTS

Birmingham

The first General Meeting of the session was held at the Grand Hotel on 17th October. Because of indisposition, Mr. Christie, the Chairman, was not able to preside, and his place was taken by the Vice-Chairman, Mr. L. Hale.

Mr. Hale apologized for not having a Chairman's address but went on to speak of the future of the Institute. He hoped that during the coming year all members would be instrumental in bringing to meetings all those interested in welding, whether they were members who had not previously attended or the guests of members. Mr. Hale stressed that audiences should include young people from the electrical, mechanical, and civil engineering organizations, and also others from kindred technological societies.

With the necessary re-arrangement of plans Mr. Mortimor, a member of the Branch Committee, showed a film on the building of the Dounreay reactor in place of the accustomed Chairman's address. The forty-five or so in the audience considered that this film described one of the finest endeavours of engineering. K.P.

Sheffield and District

The winter session commenced on Monday, 29th September, with a visit to Robert Jenkins & Co., which was very successful and the attendance a record for any works visit.

On Monday, 13th October, Mr. D. B. Tait gave a lecture on 'Developments in Gas Shielded Processes for the Welding of Mild Steel'. About 60 people attended this lecture and a very pleasing feature was the fact that they included a number of students from the Chesterfield Technical College. After the lecture there were numerous questions answered by the speaker.

It is the intention of the Branch Committee to notify all Technical Colleges in the area of any lectures which they think may be of interest to their students, as they feel they should have every encouragement to attend. J.S.W.

Wolverhampton

The first meeting of the 1958–59 Session was held at the Holly Bush Hotel, Wolverhampton, on Wednesday, 15th October, when the new Chairman, Mr. M. R. Liddiatt, presented his address. Before the address the Chairman was invested with the badge of office by Mr. R. W. Allan, past Chairman of the Branch.

A novel and interesting technique was used by Mr. M. R. Liddiatt, in presenting his inaugural address. Instead of expounding upon his considerable experience as a metallurgist, he chose to undertake a comprehensive research project covering the history of the Wolverhampton Branch. This was described from the time when the Midland Branch was founded in 1932. In just over ten years a separate section was formed in Wolverhampton under the guidance of Mr. E. Flintham and the late Mr. C. Onions. Two years later this was formed into a new Branch of which Mr. Flintham was elected Hon. Secretary. Under the Presidency of Mr. Howard Thompson the Branch grew from strength to strength and in many ways led the organization and activities of the Institute as a whole. Such things as organized works visits and the use of a No. 2 Banking Account were originated by the Branch and it has always been well represented on national and international committees.

Mr. Liddiatt described the importance of technical education in furthering the work of the Institute and mentioned in particular the activities of the local Technical Colleges. He said that many of those studying for National or City and Guilds Certificates would benefit considerably by taking part in the many and varied activities of the Branch. He expressed the hope that many of these people, particularly craftsmen, would accept this invitation, for they are assured of a warm welcome.

As an example of how informative a technical meeting can be, Mr. Liddiatt concluded his address by showing a film entitled *The structure and properties of steel*, published by the British Iron and Steel Federation. The film was divided into separate sections covering grain structure, composition, heat treatment, etc., and was extremely well presented.

In proposing a vote of thanks, Mr. D. Llewellyn made an amusing play on the word 'cementite', prominently used in the film, and Mr. C. Spencer, in supporting the motion, referred to Mr. Liddiatt as a 'well tempered' personality who he was certain would ensure the well-being of the Branch throughout his term of office. B.K.B.

NAMES AND ADDRESSES OF BRANCH SECRETARIES

Birmingham: J. R. MERTHER, 9 Brook Street, West Bromwich, Staffs.

Eastern Counties: J. A. EDWARDS, Corner Ways, Fingeringhoe Road, Abberton, Nr. Colchester, Essex

East Midlands: K. HOUGHTON, 20 Shirley Road, Leicester

East of Scotland: R. D. BERRY, 13 Craig's Gardens, Edinburgh, 12, Scotland

Indian: c/o The Association of Engineers, 24 Netaju Subhas Road, Calcutta, 1, India

Leeds and District: M. W. PARKINSON, 1106 Leeds Road, Woodkirk, Dewsbury, Yorks.

Liverpool: H. R. COX, 21 Oaklands Drive, Bebington, Cheshire

Manchester: E. H. LEE, 349 Moorside Road, Flixton, Lancs.

North Eastern (Tees-side): F. G. BATCHELOR, 5 Dionysia Road, North Ormesby, Middlesbrough

North Eastern (Tyneside): T. S. NICOL, Bolbec Hall, Newcastle-upon-Tyne

North London: J. F. GIBBS, 927 St. Cambridge Road, Enfield, Middx.

Preston: R. ROBINSON, Daneham, Pope Lane, New Longton, Preston, Lancs.

Sheffield and District: J. S. WARING, Robert Jenkins & Co. Ltd., Wortley Road, Rotherham, Yorks.

Southern Counties: J. H. GILLESPIE, 12 Burlington Road, Southampton, Hants.

South London: DR. M. C. NICKSON, 180 Charlton Road, London, S.E.7

South Wales: R. E. PHILLIPS, 20 Bryn Road, Brynmill, Swansea

South Western: G. R. THOMAS, 2 Newcombe Drive, Stoke Bishop, Bristol 9

West of Scotland: H. H. MACKINTOSH, 144 St. Vincent Street, Glasgow, C.2

Wolverhampton: J. W. GETHIN, John Thompson Ltd., Group Research Laboratories, Ettingshall, Wolverhampton

THE INSTITUTE'S VICE-PRESIDENTS

1—E. Seymour-Semper, M.I.Mech.E.

Mr. Seymour-Semper was educated at Wakefield Grammar School and at King Edward VII School, King's Lynn, and later in the Faculty of Engineering at the University of Sheffield. He had his first contact with welding at the University, and on completing his course he went into the works of Buckley Saunders & Co., who were the successors to the Pontelec Welding Co. Subsequently he joined the sales side of the company and then founded a welding business in Leeds.

A few years later he joined Allen Liversidge as Technical Sales Representative for arc and resistance welding, in the North of England. He remained with the company when it was absorbed by the British Oxygen Co. Ltd.

At the outbreak of the Second World War Mr. Semper was for a short time Manager of Oxy-Ferrolene Ltd., and then joined the Advisory Service on Welding of the Ministry of Supply, where he was responsible for advice to industry on gas welding and cutting. At the end of hostilities he founded the business of Weldcraft Ltd., and joined Hancock & Co. (Engineers) Ltd. as Sales Manager. He is now Managing Director of that Company and Chairman of Weldcraft Ltd.

Mr. Semper has had an active association with the Institute of Welding since 1923 and was a Founder Member of the original body, the Institution of Welding Engineers. In 1925 he organized the first provincial meeting of the Institution at Leeds, and was associated with the formation of the Manchester Branch more than twenty-five years ago. He was also concerned with the formation of the Leeds and Sheffield Branches of the Institute. When the South London Branch was formed in 1946 he was the first Chairman and later succeeded Sir William Larke as President.

He has been a Member of Council of the Institute for many years and has served on most of its committees, and so has been actively concerned in many of the developments that have taken place. In particular he played a leading part in the establishment of the School of Welding Technology.

The International Institute of Welding has also had the benefit of Mr. Semper's guidance, for he has for some time been the British delegate on Commission I (Gas Welding and Cutting) and is Chairman of Sub-Commission IB on oxygen cutting.

Mr. Seymour-Semper has recently been elected President of the British Acetylene Association. He is a Member of the Institution of Mechanical Engineers, and is a Member of Council of the Society of Engineers. He is the author of many papers presented to the Institute and other bodies on welding and cutting, and has written the only British text book on Oxygen Cutting.

CONTRIBUTORS TO THE JOURNAL

G. A. Phipps, a Research Officer with the British Welding Research Association, was born in South Wales in 1926. He was educated at Hafodyddol Secondary School, Mon., and at Cambridge County High School.

After four years' service in the R.A.F. he took a mechanical engineering course at Cambridge Technical College, from 1950 to 1956. He also took a post-graduate course at Sheffield University on the industrial applications of electronics, and studied industrial administration.

Mr. Phipps has been with the Research Association since 1949, and has worked on various aspects of resistance welding. He recently joined the Welding Process Group to investigate the CO_2 welding of thick mild steel plate, and the spatter problem that arises with this process.

R. E. Lismer, F.I.M., Surveyor for Metals in the Engineering Research Department of Lloyd's Register of Shipping, was born in 1915. He was educated at Nether Edge Grammar School, Sheffield, and studied metallurgy at Sheffield University. He was awarded an Associateship in Ferrous Metallurgy in 1937. He was elected an Associate of the Institution of Metallurgists in 1946 and became a Fellow in 1952.

From 1933 to 1952 Mr. Lismer was a member of the Research and Development Department of The United Steel Companies Ltd., and has since been in the Research Department of Lloyds.

Mr. Lismer is the author of a paper in the November issue of the *Journal*.

H. V. Huxley, a Development Engineer in the Weston Division of Bristol Aircraft Ltd., completed his full-time education at the Newport Technical College. He then took employment as assistant in the science laboratories of a public school, and there gained further experience in chemistry and physics.

Mr. Huxley joined the Bristol Aeroplane Co. in 1937 to work in the material inspection laboratory. Three years later he took charge of a similar laboratory at the shadow factory established at Weston super Mare, and returned to the parent company at the end of the War. He then took up his present appointment at the Banwell rocket motor development factory, and now has charge of a section working on the development of high-strength weldable steels.

G. A. Phipps

R. E. Lismer

H. V. Huxley

BRITISH WELDING RESEARCH ASSOCIATION

Council

Sir Donald Bailey, Kt., O.B.E., J.P., Director of the Ministry of Supply's Military Engineering Experimental Establishment at Christchurch, Hants. (usually known as M.E.X.E.) has been co-opted to the Council of the Association. Sir Donald is well known as the engineer who invented the Bailey Bridge, which was used by the British Army during its advance across Europe. Assembled from welded panels connected by pinned joints and originally of steel, it is now more often built of light alloys.

New Staff at Abington

From research flows a mass of measurements in which it may be extremely difficult to arrive at conclusions. Since mathematics can often extract from these measurements conclusions that could not have been reached without it, a mathematical section has recently been formed at Abington, consisting of Dr. A. I. Martin, consultant mathematician, Mr. J. C. Amson, and Mrs. M. S. Toms. Some possible applications of mathematics to welding research exist in heat flow, elasticity, plasticity, fracture, fatigue, and of course in the statistical examination of test results.

Dr. Martin has a background of aviation, having worked on vibration analysis for the Bristol Aeroplane Co. Ltd., and having studied supersonic flow over missile wings for A. V. Roe & Co. Ltd. His work for B.W.R.A. is one facet of his mathematical consultancy service. In this he expects to help organizations to discharge their research duties in some of the following ways: (1) the solution of engineering or industrial problems which have been formulated mathematically; (2) helping management or

research workers to state their problems in a mathematical form; (3) surveys of the scope for applying mathematics to the problems of any particular organization.

Dr. Martin has been making one such "mathematical survey" for B.W.R.A. during the last few months, but it is not yet known whether this survey can be published.

Mrs. M. S. Toms, B.Sc., A.R.C.S., obtained her honours degree in mathematics at the Imperial College. She is one of the few women in this country with engineering experience and was for a short time an engineering apprentice at the Royal Aircraft Establishment, Farnborough. She regards herself as a founder member of the I.B.M. scientific computing service which uses electronic computers and punched cards. Last year she moved to Cambridge with her husband, doing some punched card computing in economics, and was thus able to join the B.W.R.A. mathematical section.

Mr. John C. Amson, B.Sc., obtained a first-class honours degree in mathematics at Reading University, where he was Chairman of the Mathematical Society. He has been a member of the London Mathematical Society since 1954 and is also a member of the Mathematical Association. His chief interests are in fundamental research and the application to it of mathematical techniques.

Other new staff includes:

Mr. Frank R. Coe, B.Sc., Chief Chemist at Abington Hall, took his degree at Birmingham University, like several of the non-ferrous metallurgists in B.W.R.A. He spent his two years' military service at Catterick Camp as an instructor, training men to be radio-mechanics. When he left the army he joined the Research Department of I.C.I. (Metals Division) in Birmingham as an analytical chemist. There he worked on the development of methods of analysis for non-ferrous alloys including titanium, particularly on electro-chemical procedures. He has worked on polarography in metal analysis and has developed an electrometric method for determining chloride in titanium and zirconium. This technique is expected to arouse wide interest, and will be published soon in the *Analyst*.

Mr. Stephen W. Neville, who is working on vibration welding at Abington Hall, obtained a London University B.Sc. (Eng.) degree from Acton Technical College at the early age, for an external degree, of 22. He spent six years working for the De Havilland Engine Co. Ltd. under their Aeronautical Technical School apprenticeship scheme.

Mr. D. S. Macfarlane, B.Sc., who was born in Edinburgh, has a degree obtained at Glasgow University. Before joining the B.W.R.A. he did vacation work with several aeronautical firms. He is working on thermal stresses, and the application of three-dimensional photo-elastic stress-freezing techniques to the analysis of pressure vessels.

Dr. J. van Lohuizen, who has recently taken over the library at Abington Hall, holds a Ph.D. of Cambridge University. His first degree was obtained at Utrecht.

Mr. K. J. Clews, A.M.Inst.W., is a metallurgist who joined B.W.R.A. from the research department of I.C.I. (Metals Division). He investigated the manufacture of fuel elements in the early days of atomic energy and was then seconded to Marston Excelsior Ltd., where he was responsible for metallurgical control and research on the flux-dip brazing of aluminium alloys as well as the introduction and development of furnace brazing techniques for stainless steel, the Nimonic alloys and titanium. More recently Mr. Clews has been concerned with the welding of aluminium alloys copper and aluminium bronze, and also with the gas-shielded tungsten-arc process for cutting metals. He holds patents relating to an arc-starting method and to an improved cutting torch.

Mr. J. M. Wheatley, B.A., is investigating the metallurgical side of Abington investigations into the brittle fracture of steel. Born and educated near Newcastle-upon-Tyne, he obtained Honours in the Natural Sciences Tripos Part I at Cambridge in 1953. He read metallurgy from Part II, and later did research on fatigue in powdered metal compacts, also at Cambridge.

Mr. R. N. Younger, B.A., was born in Scotland and was educated at Winchester and Magdalene, Cambridge, where he took Honours in metallurgy. He joined B.W.R.A. in September and is investigating the welding of austenitic stainless steels.

OTHER SOCIETIES

Behaviour of metals at low and high temperatures

Brittle fracture phenomenon and high temperature creep of metals are among the topics for discussion at a Conference provisionally arranged by the British Society of Rheology to be held at the University of Leeds on 8th and 9th January, 1959. Full details may be obtained from the Hon. Secretary: Mr. N. Wookey, 52 Tavistock Road, Edgware, Middx.

British Standards Annual Report

Current work in hand on welding standards is described in the recently published Annual Report of the British Standards Institution. A revised edition of BS.2493 now covers 4 types of low-alloy electrodes, and is renamed "Molybdenum and Chromium Molybdenum Low-alloy Steel Electrodes for Manual Arc-welding"; this should be ready for publication early in 1959. New standards will be published shortly for projection welding of studs, bosses, annular rings, etc., and for manual inert-gas tungsten-arc welding of wrought aluminium, aluminium alloys and magnesium alloys. It is hoped to prepare a new standard to cover stainless steel and inert-gas metal-arc welding of aluminium and its alloys.

The drafts of two new standards for the rating of resistance welding machines and Class II metal-arc welding of steel pipelines and pipe assemblies, respectively, should be ready for comment in the near future.

The ISO/TC44 Welding Committee has been active during the year. Draft proposals have been prepared for the determination of the strength of the weld joint and characteristics of the deposited metal when using gas welding filler rods; dimensions and pitching of tee-slots in platens for resistance welding equipment; and an appendix of test methods to determine whether an electrode is deeply penetrating. Draft proposals for rating arc-welding equipment were accepted subject to the Sub-Committee's consideration of an additional clause on commutation. Documents on rating of resistance welding equipment and on spot welding electrodes were referred back. The Committee also discussed the preparation of a recommendation on the safety of welding equipment.

Canadian Welding Bureau

The Bureau is again holding a series of courses of instruction for welding personnel in supervisory, foremanship or leadership positions. The Bureau is also holding a course on blueprint reading and another on welding codes, standards, and specifications.

A course of 14 lessons on Weld Quality Control and Inspection ended on 21st June for welding inspectors. All those who successfully met the requirements of the Bureau received a diploma. This form of education, conducted mainly in the form of correspondence courses, has been running for the past 10 years, but supplementary lectures are arranged in convenient centres to assist the students in their studies.

Some 30 building officials and inspectors, of Toronto, recently participated in a practical course of welding instruction under Mr. Harold Howard, chief instructor, at the Ryerson Institute of Technology. The intention of the course was to better acquaint inspectors with the practical problems of welding so that they might be able to seek out defects more intelligently and be able to assess the degree of deficiency involved.

When the school facilities become available again next summer, the Bureau hopes to conduct another practical course for members of professions.

Dr. S. Livingston Smith

After a lengthy illness, Dr. Livingston Smith, C.B.E., M.I.Mech.E., has died at the age of 69.

Dr. Smith was the first Director of Research of the British Shipbuilding Research Association, set up in 1944. Besides his connections with many other organizations he has been associated for many years with the work of the British Welding Research Association and he was an original member of the Admiralty Ship Welding Committee.

NEWS FROM INDUSTRY

Brussels Exhibition awards

Against world competition, Babcock and Wilcox Ltd. have received the highest award in any category—a Grand Prix in the major category of Production of Electrical Energy, at the Brussels Exhibition. The Company has also been awarded two gold medals in the categories: Exploration of Nuclear Energy and Shipbuilding. This reflects the Company's prominent position in the field of nuclear power and marine propulsion. In addition, a Diplome d'Honneur, also a high distinction, has been awarded to the Atomic Power Group, comprising English Electric, Babcock and Wilcox, and Taylor Woodrow, in the category Exploration of Nuclear Energy. This exhibit was devoted mainly to the design and construction of the atomic power station at Hinkley Point.

A Gold Medal for Construction of Equipment Utilizing Electricity, and a Bronze Medal for Welding, Brazing and Cutting, have also been awarded to Bates & Bates Ltd., for their display of resistance

welding equipment at the Engineering Centre Collection Exhibit.

Sixth nuclear power station

Application is being made to the Ministry of Power and to the Local Planning Authority for consent to develop a site at Sizewell in Suffolk for the sixth nuclear power station to be built by the Central Electricity Generating Board. The proposed power station will have an output capacity of about 650,000 kW and will be connected to the 275,000 V national grid system.

Three nuclear power stations are now under construction by the Board at Berkeley, Gloucestershire (275,000 kW); Bradwell, Essex (300,000 kW); and Hinkley Point, Somerset (500,000 kW). Preparation has been started for the construction of a fourth station at Trawsfynydd, Merionethshire (500,000 kW) and application has been made to develop a site at Dungeness for the fifth station.

Roofing units

Prefabricated large-span roofing units in the form of welded steel arches under tension are being manufactured in the new factory of Modern Engineering (Bristol) Ltd. The roof of the new building is constructed of these units, which give clear spans of 70–210 ft and have a loading capacity of 15 tons. Natural lighting, acoustic and insulating characteristics are unusually high.

Diesel-hydraulic locomotives

The first of 33 British built main line diesel-hydraulic locomotives recently completed its trials in the Western Region of British Railways. Welding is used extensively in the construction of these locos, which are based on the successful V200 design of the German Federal Railways. By the use of stressed-skin construction for the superstructure the body weight has been reduced by 30–40 tons, equivalent to the weight of one coach.

The two 4-wheeled bogies are fabricated from mild steel plate.

Low-pressure acetylene generators

Requirements for the design and operation of low-pressure acetylene generators and ancillary apparatus have recently been published by the British Acetylene Association (price 7*s*. 6*d*. from 101 Leadenhall Street, London E.C.3).

The publication gives definitions and follows with specifications for stationary and portable generators, liquid-sealed gas holders, flashback arrestors and hydraulic back-pressure valves, purifiers and purifying materials, scrubbers, filters and dryers, and has a final section on safe practices.

Lloyds notice

Welding of aluminium alloys and engine frame components, requirements for aluminium, and notes on beam knees and rudders form the main subjects of Notice No. 2120 issued by Lloyds Register of Shipping.

Revision has been made to the tentative requirements for aluminium alloys and a section specifying the welding processes has been added.

Rules for welded structures for steam reciprocating and heavy oil engines have also been introduced. An outline of the welding procedure and fabrication methods must be submitted before any work is started. All materials are to be tested for welding quality to approved specifications with carbon content generally not more than 0·23%. Steels with higher carbon contents may be approved, subject to special weldability tests.

The requirements include information on design details such as position of joints and the avoidance of abrupt changes of section in the material. The number of specific steel alloys tabulated for steam pressure pipes has been doubled.

Stud welding award

The 2nd annual Gregory Award, presented for the year's most outstanding contribution in the field of semi-automatic

J. C. Chapman

electric-arc stud welding, has been won by Dr. J. C. Chapman for his paper "*The Application of Stud Welding to Vibrating Wire Strain Gauges*".

Dr. Chapman, who is a member of the Civil Engineering Department of the Imperial College of Science and Technology, received the Award at a luncheon of the American Society of Metals in Cleveland, Ohio, on 28th October.

The paper describes how the anchorage studs for acoustic strain gauges were stud welded to members of the steel frame of the new Mechanical Engineering Building at Imperial College. This is the first building to be erected in Britain which has castellated floor beams, with reinforced flanges designed to act compositely with the floor slabs by means of stud-welded shear connectors.

Because of the unusual nature of the design it was decided to make a record of the structural behaviour of the whole of the construction during erection and subsequent use. To ensure stability during long periods of operation, the vibrating wire, or acousitc type strain gauge was selected. The new model, described in the paper, is an improvement on earlier types using threaded studs screwed into tapped holes, in that it provides greater long-term accuracy and is much simpler to install and adjust.

A single template was used to locate and align the six studs needed for each gauge, and forty-two gauges were installed, with the use of Crompton-Parkinson 'Cyc-Arc' equipment, in two days. More than 100 similar gauges were subsequently fixed to steelwork before erection.

Wire and Sheet Gauges

The many different systems that exist for standard thicknesses of wire, sheet, and strip result in considerable confusion in industry. Attempts are being made by the British Standards Institution to help the International Standards Organization introduce a standard system based on 'preferred numbers'.

A discussion on the merits of different series, by Captain G. C. Adams, appears in the July issue of *B.S.I. News*, and an appeal for comments from all sides of industry is being made.

Further information can be obtained from the Secretary, Committee MEE/–/7, British Standards Institution, 2 Park Street, W.1.

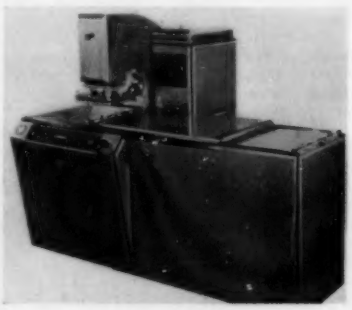
British Standards approval

The British Standards Institution has revised its Kite-mark and is anxious that the new form should be introduced by all present licencees as soon as possible. The new design incorporates the words 'Approved to British Standards'.

NEW EQUIPMENT AND MATERIALS

Thermoplastic welding machine

A new high frequency machine for welding thermoplastic materials is being produced by Maxinec of Holland. The machine



has a high frequency generator and pneumatic press complete with a fully automatic material transport table. An adjustable electrode holder with a special automatic arc limiting device is incorporated in the machine. F. J. Edwards Ltd. are the sole agents in the United Kingdom.

Land Rover welder

A convenient source of mobile welding current is now available for use in practically any place with the introduction of the series II Land Rover diesel engined unit. Lincoln Electric Company Ltd. are now supplying a complete self-contained machine with a current range of 30–200 amp that can be connected direct to Land Rovers fitted with a rear power take off.

Fillet weld measurement

For the measurement of fillet welds of $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ in. leg length, Rockweld

Ltd. now supply an inexpensive pocket gauge. It is made in blue anodised aluminium with silver markings, and is priced at 1*s.* 6*d.*

Like most gauges of this type it will measure accurately only fillet welds with equal legs and with fairly flat profiles.

BB Hot Blast Torch

A brief announcement of a new gas torch was made in the News section of the September issue of the *Journal*.

Preheated gas–air torch, using town gas, making a horizontal-vertical fillet weld. The welder does not need to wear goggles.

This torch was recently demonstrated to the public for the first time in Bristol. Developed by Dr. C. R. Burch of Bristol University, the torch is being marketed in Britain by the BBS Development & Manufacturing Co., Bristol.

It is a preheated gas-air torch, operated from town gas mains at normal pressure and air at 0·5 lb/sq.in. The flame temperature is above 2000°C., which will melt platinum wire, and it is particularly suitable for welding and flame brazing aluminium alloys, brass and copper, and magnesium and silver soldering.

Lightweight blowpipe

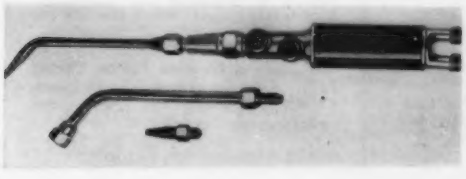
A new TS high pressure blowpipe which weighs only 15 oz. has been introduced by Weldcraft Ltd. At this light weight it is ideal for use by female labour on sheet metal and light repetition work. A range of swaged copper nozzles are available in place of the nine standard nozzles specified for welding steel from $\frac{1}{32}$ to $\frac{1}{16}$ in. thick. A cutting attachment will be introduced later. The basic set comprises a blowpipe with neck and six nozzles for welding up to $\frac{1}{8}$ in. thick steel. Other sets are available and include; 6 swaged nozzles (TS2), 9 standard nozzles (TS3) and 9 swaged nozzles (TS4).

Gas consumption is quoted to be 1 cu.ft/hr with No. 1 nozzles to 25 cu.ft/hr with No. 9 nozzle, depending on the skill of the operator and the mass of metal being welded. Oxygen pressure varies from 3 to 7 lb/sq.in. The blowpipe is not suitable for use with acetylene produced by low pressure generators.

Resistance casting

Recently demonstrated at the Open Day of the British Welding Research Association at Abington, a discovery in resistance welding, provisionally patented, is now being developed there. The discovery evolved directly from work done at Abington for the United Kingdom Atomic Energy Authority.

In resistance spot welding, molten metal is expelled if the welding current is too high or if the electrode force is too low. This molten metal can be directed into a cavity in the welding face of an otherwise normal spot welding electrode. Since it freezes there to form a stud, strongly welded to the parent sheet, the technique is known as resistance casting, or sometimes as stud raising, or pimple welding.



Lightweight Weldcraft TS high-pressure blow-pipe for sheet metal work.

Studs of varied shapes and sizes have been formed by this process in a wide range of metals, including steel, stainless steel, light alloys, titanium, and nickel alloys. A peg of similar or different material, inserted in the electrode cavity, can be cast into the stud; strong metallic bonding between the peg and stud can occur with compatible metals, though the purely mechanical joint formed with non-metallic pegs may also be strong. If both electrodes are provided with a cavity, projections will be formed on both sides of the article. Since the metal for the stud is drawn from the molten spot weld nugget it is generally necessary to have at least two sheets of metal between the spot welding electrodes to raise a stud.

It is proposed to undertake a survey of possible industrial applications for the new process, but some are already obvious. Amongst the less obvious ones are the raising of projections on tubes or flat surfaces to form heat exchangers. Projections suitable for projection welding can be made by resistance casting on metal too thick to be raised by pressing.

Readers' suggestions for suitable applications should be sent to the Editor.

Cutting of shallow chamfers

A method of machine gas-cutting of 'lazy' or shallow angle chamfers has been used at the West Hartlepool dockyard of William Gray & Co. Ltd. for the past two years. By the use of an extra rack and pinion, a B.O.G. 'Bantam' cutter can be set to produce a one in five angle of cut. Weights are used to counterbalance the modified cutter arrangement.

Shallow chamfer being cut from 1¾" thick plate with a modified 'Bantam' cutter.

The illustration shows a cut being made in 1¾ in. thick plate at a speed of about 6 in./min. The depth of cut is 4 in.

Finishing of welds

An addition to the Stanley range of tools, recently introduced, is the Stanley 'Shaper', which is likely to find many applications in the fabricating shop.

The working surface is a specially heat-treated pierced blade, which is claimed to shape and finish most surfaces, including

Aluminium weld being dressed with a Stanley 'Shaper' tool

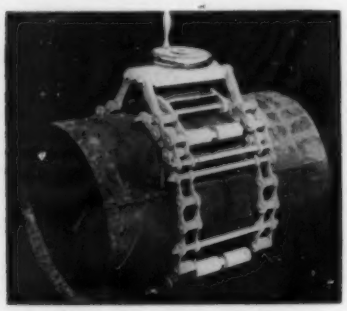
mild steel. Teeth extend round the edge of the blade so that corners and concave surfaces can be filed.

The illustration shows a shaper being used on a weld in an aluminium alloy.

Aligning pipes for butt welding

By a modification and improvement of their existing 'chain' pipe clamps, Courtburn Positioners have produced a more versatile adjustable pipe clamp that will accommodate a wide range of pipe sizes.

The illustration shows clearly the operation of the clamps, which are designed to



allow ample clearance for tack welding. There are three standard sizes to cover the range 6 to 24 in., but larger sizes can be made if needed.

Pre-coated steel sheet

John Summers & Sons Ltd. have produced a steel sheet coated with nickel and a protective coating of zinc for vitreous enamelling. The material "Nitec" is stated to be weldable by all accepted methods, and the welding conditions are not very different from those for uncoated steel.

DIARY

2nd Dec.—North London (Slough Section)—*Welding in Nuclear Engineering* by A. Prince (Community Centre, Slough, 7.30 p.m.)

3rd Dec.—Manchester—*Welding in the Rocket Motor Industry* by F. J. Wilkinson (College of Science and Technology).
North London—*Fatigue and Brittle Fracture Aspects of the Design of Plate Girders* by E. M. Lewis (54 Princes Gate, 7.30 p.m.)

4th Dec.—South Western—Welding Forum. Joint meeting with Gloucester Assoc. of Engineers (Radiant House, Gloucester, 7.15 p.m.)
Birmingham—Annual Dinner (Grand Hotel).
Leeds—Annual Dinner (Mansion Hotel, Roundhay, Leeds).
West Wales—*Automatic Welding* by W. E. Freeth (Neath Technical College).
North Eastern (Tyneside)—*Use of Welding in Ship Repair Work* by A. Bowman.
Eastern Counties—*Plastic Theory of Structures* by T. M. Charlton (Norwich).

6th Dec.—North Eastern (Tyneside)—Annual Dinner.

8th Dec.—Sheffield—*Argonarc Welding of Corrosion and Heat Resisting Steels* by J. A. McWilliam. Joint meeting with Sheffield Branch, Inst. Prod. Engineers (Grand Hotel, 7.15 p.m.)

9th Dec.—Liverpool—*Some Problems of Management* by R. R. Butler (College of Technology, Byron Street).

10th Dec.—*Hydrogen in Steel.* Joint meeting with Iron and Steel Inst. (Weir Lecture Hall, Inst. Naval Arch., 10 Upper Belgrave St., 2.30 p.m.)
Wolverhampton—*The Culture and Specialization of Metallurgy with Welding Progress* by D. Llewellyn (Holly Bush Hotel, 7.30 p.m.)
East Wales—*Class I Fusion Welded Mild Steel Pressure Vessels* by A. H. Briscoe, and colour film *Welding of High Pressure Boiler Drums* (S.W. Inst. Eng., Cardiff).

11th Dec.—Southern Counties—*Some Aspects of Tanker Construction* by L. Johnson.
South London—*Electrode Development* by J. F. Mercer (54 Princes Gate, 7.30 p.m.)
Eastern Counties—*Resistance Welding* (Colchester).

12th Dec.—Birmingham—*Selection and Use of Arc Welding Processes* by E. Flintham (Grand Hotel, 7.30 p.m.)

16th Dec.—Leeds—*High Production and Automatic Welding* by J. A. Lucey (Gt. Northern Hotel, Leeds, 7.30 p.m.)
East Midlands—*Scope and Limitations of Metal Spraying* by R. Gallagher (Welbeck Hotel, Nottingham, 7.15 p.m.)

17th Dec.—West of Scotland—*Why Weld Automatically?* by I. C. Fitch.
North Eastern (Tees-side)—Open Discussion.

1959

5th Jan.—South Western—To be arranged (Radiant House, Bristol, 7.15 p.m.)
Sheffield—Annual Dinner (Royal Victoria Hotel).

6th Jan.—South Western—*Metal Spraying* by G. Payne (Radiant House, Bristol).

7th Jan.—Manchester—*Fabrication of Stainless Steel* by B. Banks (College of Science and Technology).

8th Jan.—South London—*Practical Significance of BWRA Work on Gas Shielded Welding Processes* by A. A. Smith (54 Princes Gate, 7.30 p.m.)
North Eastern (Tyneside)—*Welding from the Viewpoint of Lloyd's Register* by G. M. Boyd.

12th Jan.—Sheffield—Talk and film on the *Jodrell Bank Telescope* by C. N. Kingston. Joint meeting with Rotherham Eng. Soc. (Rotherham Technical College, 7.15 p.m.)

STUB ENDS

▶ Major price reductions over their whole range of resistance welding control equipment have been made by Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.

▶ A special electric tool safety poster has been designed and prepared by Wolf Electric Tools Ltd. in conjunction with the British Safety Council. Copies of the poster and a full length article on safety with portable power tools is available on request from Industrial Publicity Dept., Wolf Electric Tools Ltd., Pioneer Works, Hanger Lane, London, W.5.

▶ Mr. C. A. Henderson has been appointed General Manager of Eutectic Welding Alloys Co. Ltd.

▶ Whessoe Ltd., of Darlington, have regrouped their departments dealing with design, tendering, and development to form an Engineering Division, The new division will compliment the existing Works and Erection Divisions. It is being managed by Mr. R. F. Bishop, who formerly led the Special Projects department.

▶ The United Steel Companies Ltd. have issued a revised version of their 'Layman's Guide' to the Factories Acts 1937 and 1948 and how it affects the Iron and Steel Industry. Copies may be obtained free of charge from the Welfare Office, The United Steel Companies Ltd., 17 Westbourne Road, Sheffield, 10.

CLASSIFIED ADVERTISEMENTS

Situations Vacant

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have a vacancy in their Rocket Motor Organization for a **Senior Welding Metallurgist.** A degree in engineering or metallurgy and/or equivalent professional qualification is essential.

The applicant will be required to control a group of technicians concerned with the development of new projects in ultra-high tensile steels and non-ferrous metals. Familiarity with automatic welding processes and experience of carrying out programmes of experimental work requiring initiative and practical application is desirable.

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who will be responsible for the investigation of welding problems and the overall supervision of all welding on plate-, pipe- and structural-steel work. Applicants must be fully conversant with welding theory and practice. The successful candidate will be based at Cheadle Heath but will make site visits from time to time. This appointment is a senior one and will be permanent and pensionable. Starting salary £1500 to £2000 p.a. (Ref. CH.32).

(2) **A WELDING ENGINEER**

who will be responsible to the Chief Welding Engineer and will supervise welding on site. Applicants must be fully conversant with welding theory and practice. It would be desirable for the successful candidate to reside on the South side of Glasgow. This position is permanent and pensionable. Starting salary from £1000 p.a. (Ref. CH.33).

Send brief relevant details to **Staff and Training Division, Simon-Carves Ltd., Cheadle Heath, Stockport, Cheshire,** quoting the appropriate reference number.

Current WELDING LITERATURE

Book Reviews
Additions to the Institute Library
Trade Publications

CONTENTS OF PERIODICALS RECEIVED

THIS SECTION is intended to give a survey of the current welding literature received by the Institute of Welding Library. The contents lists are not exhaustive; only the main articles in welding journals are listed, and reprints from other journals and short notes are generally excluded. In addition, welding articles from other periodicals are listed. Abstracts of welding literature are given in the *Bibliographical Bulletin of Welding and Allied Processes*, published by the International Institute of Welding, and details of this may be obtained from the Secretary of the Institute of Welding.

Welding Journals

Schweissen und Schneiden (Germany), 1958, vol. 10, August

Position, time, and cause of spatter during electric-arc welding, F. Erdmann-Jesnitzer and G. Pysz (303–311)

Fatigue tests of brazed pipe connections, J. Colbus (312–316)

Trend of production, exports, and imports of electric welding equipment in 1957, A. Gese (316–320)

Considerations concerning the application of automatic welding processes, K. H. Mathias (321–327)

Repair of a ball type grinding mill by weld deposits on large areas, G. Kohlhaupt (327–330)

Przeglad Spawalnictwa (Poland), 1958, vol. 10, September

Powder cutting, Pt. 2, W. Szydlik

Alloy electrodes for copper welding, J. Wegrzyn

Canadian Welder, 1958, vol. 49, August

A selection guide for submerged arc welding methods, M. N. Vuchnich (12–16)

School for pipeline welders (17)

Germans use welded design in blast furnace construction, W. Wallis (18–19)

Electronic flame-cutting machine control (22)

Soudages et techniques connexes (France), 1958, vol. 12 July–August

Deep penetration welding with covered electrodes. Studies carried out by the Institute of Welding. IV—Results (Pt 2): Effect of electrical characteristics on the extent and uniformity of penetration. Studies relative to the soundness and mechanical characteristics of joints, A. Gaubert (249–262)

Effect of storage time on hydrogen content and mechanical properties in arc welds made with covered electrodes (I.I.W. Commission 2), W. Hummitzsch (269–276)

Welding in the equipment of the works for the extraction of plutonium at Marcoule, P. Couturier (277–387)

Recommended practices for radiographic inspection of fusion welded joints for steel plates up to 2 inches (I.I.W. Commission 5) (291–294)

Determination of the experimental laws of flicker in view of their application to low voltage systems subjected to periodical or aleatory variations of loads (welding machines, starting motors). Experimental devices for the study of flicker, P. Ailleret, A. Dejou, and P. Gaussens (297–317)

Industry and Welding (U.S.A.), 1958, vol. 31, September

Four headed automatic unit makes 110 foot welds without a stop (34–35, 44–45)

How would you braze all-metal honeycombs? (36–37, 73)

Automatic cross wire welding at 900 i.p.m. (38–39, 74)

Fixturing for butt welding stainless sheets cuts production from 30 minutes . . . to 10 . . to 2½ (40–43)

When the job can't be moved, D. L. Caldwell (48)

Stress-relieving without a furnace (50–51)

Preheating and postheating chrome-moly steel piping (Production and engineering data) (52, 54–5)

Australian Welding Journal, 1958, vol. 1, July

Design for welded structures, N. G. Hosking (15–19)

Welded main beams for 85 ton transformer carrier (27–28)

Welding 'hazards'. Our modern-day mythology, T. B. Jafferson (31–34)

Welding Journal (U.S.A.), 1958, vol. 37, September

Design for production by welding, John Mikulak (871–881)

Inert gases for controlled-atmosphere processes, E. F. Gorman (882–889)

Submerged-arc welding of uranium, G. S. Hanks, J. M. Taub, and E. L. Brundridge (890–896)

An investigation of lap seam welds in 17–7 Ph stainless steel, E. J. Funk and A. C. Willis (897–905)

Comparisons between welds in iodide- and sponge-base titanium alloys, W. J. Lewis, M. L. Kohn, and G. E. Faulkner (385s–390s)

Correlations of brittle-fracture service failures with laboratory notch-ductility tests, P. P. Puzak, A. J. Babecki, and W. S. Pellini (391s–410s)

Design values for thermal stress in ductile materials, B. F. Langer (411s–417s)

Control of melting rate and metal transfer in gas-shielded metal-arc welding, Pt 2—Control of metal transfer, A. Lesnewich (418s–425s)

Co-operative investigation of a new welding electrode for stainless steel, R. D Wylie (426s–432s)

Welding Production (U.S.S.R.), 1958, No. 9, September

Development prospects for welding in chemical machine-building, P. T. Dmitriev (1–6)

On the welding of plastics, A. N. Shashkov (6–9)

Welding of plastics by high frequency current, S. E. Semyatchkin and E. G. Trofimov (9–11)

On the use of low-alloy refined steels in welded structures, E. M. Kuzmak and V. C. Milantchev (11–15)

Methods for evaluation of the resistance to formation of cold cracks in welded steel, N. N. Prokjorov and E. L. Makarov (15–18)

Effect of electrode vibration on the arc welding process and the weld properties, A. A. Alov and V. S. Vinogradov (19–22)

Principal trends of scientific research work in the welding department of the Bauman Moscow High Technical School, G. A. Nikolayev (22–26)

Electro-slag welding of a water turbine shaft, A. S. Gelman and others (26–32)

Production technology of large diameter welded straight seam gas and oil pipes, S. L. Mandelberg and Kniazhinski (32–35)

Butt welding of titanium and its alloys on modernized type ACTA-300 machines, M. K. Zaburdin and others (36–39)

ADDITIONS TO THE LIBRARY

BOOKS AND PAMPHLETS

AMERICAN SOCIETY FOR TESTING MATERIALS. *Symposium on non-destructive tests in the field of nuclear energy*. March 1958, presented in Chicago, April 16–18, 1957, ASTM Special technical publication No. 223 (Price $10.00 or $7.50 to members); *ASTM specifications for steel piping materials*. March 1958, prepared by the ASTM committee A-1 on steel, December, 1957. A.S.T.M., Philadelphia (Price $5.00, or $4.00 to members)

BRITISH STANDARD 2996:1958. *Projection welding of low carbon wrought steels, studs, bosses, bolts, nuts and annular rings*. 1958, British Standards Institution, London (Price 4*s*.).
This new publication relates to welding to plate, sheet, strip and tube. Among requirements specified are those for the material and design of the electrodes and their inserts; welding procedure; weld inspection; time, condition and methods of testing, and the test results which should be achieved. An appendix to the standard lists a number of 'operating instructions' applicable to both power-operated and pedal-operated machines.

BRITISH STANDARD 3019:Part 1:1958. *General recommendations for manual inert-gas tungsten-arc welding. Part 1. Wrought aluminium, aluminium alloys and magnesium alloys*. 1958, British Standards Institution, London (Price 5*s*.) This is the first in a series for inert-gas welding. It contains recommendations on the composition and size of filler rods and wires, on equipment, joint preparation, condition of fusion faces, preheating, welding current, electrodes and argon flow rate. Details of the edge preparation required for different thicknesses and for different types of weld are given, and an appendix provides information on the equipment required.

BRITISH WELDING RESEARCH ASSOCIATION. *Report of the Council. 13th Annual Report, 1957–1958*. B.W.R.A., London (Free on request).

GREAT BRITAIN: MINISTRY OF TRANSPORT AND CIVIL AVIATION. Merchant Shipping. *Survey of passenger ships; instructions to surveyors*, vol. 1. 3rd ed., 1956, H.M.S.O., London.

INTERNATIONALES INSTITUT FÜR SCHWEISSTECHNIK. *Festschrift Anlasslich der 11 Jahresversammlung des IIW/IIS in Wien* 29.6–6.6.58. 1958, "Schweisstechnik", Wien.

INTERNATIONAL INSTITUTE OF WELDING. *IIW–IIS 1948–1958*, 1958, London (Price 14*s*.). In French and English opposite pagination. Part 1 deals with the work, organization and history of the IIW; Part 2 describes the work and nature of each Commission; Part 3 lists past and present officers, members, societies, gives list of documents and papers published and presented at public sessions of the IIW.

INTERNATIONAL INSTITUTE OF WELDING. *Multilingual collection of terms for welding processes. Gas welding in ten languages*. 1958, Association Suisse pour la technique du soudage, Basle (Price 7*s*. 9*d*.)

The Japan Science Review: Mechanical and Electrical Engineering, vol. 3, No. 1, 1956, published jointly by the Japan Society of Mechanical Engineers, the Institute of Electrical Engineers of Japan, and allied engineering societies, September 1957. (New periodical received on exchange with the Ministry of Education, Tokyo.) (Price $2.00)

MARIN, JOSEPH, and RIMROTT, F. P. J. *Design of thick-walled pressure vessels based upon the plastic range*. (Welding Research Council Bulletin series, No. 41, July 1958) W.R.C., New York (Price $1.00).

Non-destructive testing manual. Applicable to aircraft designed by Vickers-Armstrong (Aircraft) Limited, 1958, Vickers-Armstrongs (Aircraft) Ltd., Weybridge, Surrey (Price 84*s*.).

Resistance Welding Manual, vol. 1, ed. by E. J. Del Vecchio, 3rd ed., 1956, Resistance Welder Manufacturers' Association, Philadelphia.

Specification No. E.353A—Pressure vessels. Class 1 Fusion welded mild steel pressure vessels. August 1957; *Specification No. E.354A—Pressure vessels. Fusion welded mild steel pressure vessels (formerly Class 2 and Class 3 categories) including horizontal storage tanks on onerous duties*. August 1957; *Specification No. E.485—Pressure vessels. Class 1 fusion welded mild steel pressure vessels for service at sub-zero temperatures down to —50°C*. June 1958. Imperial Chemical Industries Ltd.

Tentative specifications for mild steel arc-welding electrodes. A.S.T.M. Designation: A 233-58T; A.W.S. Designation: A 5.1-58T. 1958, American Welding Society, New York (Price 50 cents).

TRADE CATALOGUES

Metrovick Arc welding electrodes. Pocket electrode guide. Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17

E.M.I. Nuclear health instruments. Hand and clothing monitor Type 1. E.M.I. Electronics Ltd., Hayes, Middlesex

Gebr. Böhler & Co. Aktiengesellschaft. Edel-Schweissdrähte. Gebr. Böhler & Co., Dusseldorf-Oberkassel, Hansa-Allee 321

The Bonderizer, vol. 7, No. 4, August 1958. The Pyrene Co. Ltd., Metal Finishing Division, Great West Road, Brentford, Middlesex

New 200–260 portable X-ray for industrial use; Portable Lightweight Andrex 160 kVp/360° X-ray unit; Portable Lightweight Andrex 130kVp automatic X-ray units; Portable Lightweight Andrex 130 and 160 kV X-ray units. B.I.X. Ltd., Hanover House, 73 High Holborn, London, W.C.1

Adjustable speed A.C. commutator-motor. Compound-characteristic Type-CC Three-phase; Adjustable speed A.C. commutator-motor. Shunt-characteristic Type-CH Three-phase. A. Reyrolle & Co. Ltd., Hebburn, County Durham

Union Carbide. Editor's facts book. 1958. Union Carbide Corporation, New York 17

Electric spot welding machines; Multiple head fabric welder; Electric seam welding machines; Patent scaling machines; Resistance welding machines; Electric rivet heaters; Electric butt welding machines; Pipe reinforcement plant. The Westminster Engineering Co. Ltd., Victoria Road, Willesden Junction, London, N.W.10

ASEAWELD products. A survey. Leaflet No. 2001 Ea; *Z-electrodes. Aseavets*. Leaflet No. 6487 En; *Z Al Aluminium electrodes*. Leaflet No. 7109 E; *Z 5P electrodes*. Leaflet No. 2516 E; *Z 8P electrode type*. Leaflet No. 6487 Ek; *Z 12P High metal yield electrode*. Leaflet No. 7189 E. Fuller Electric Limited, Fulbourne Road, London, E.17

'Vulcathene' products catalogue; 'polyfusion'—the most advanced technique for joining 'Vulcathene' with only conventional flame or electricity and a 'Polyfusion' tool. J. S. and F. Folkard Ltd., Rectory Lane, Edgware, Middlesex

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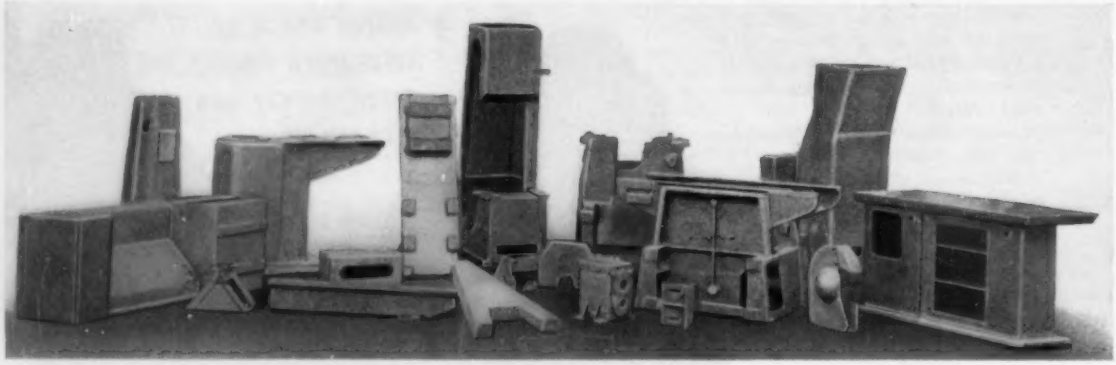

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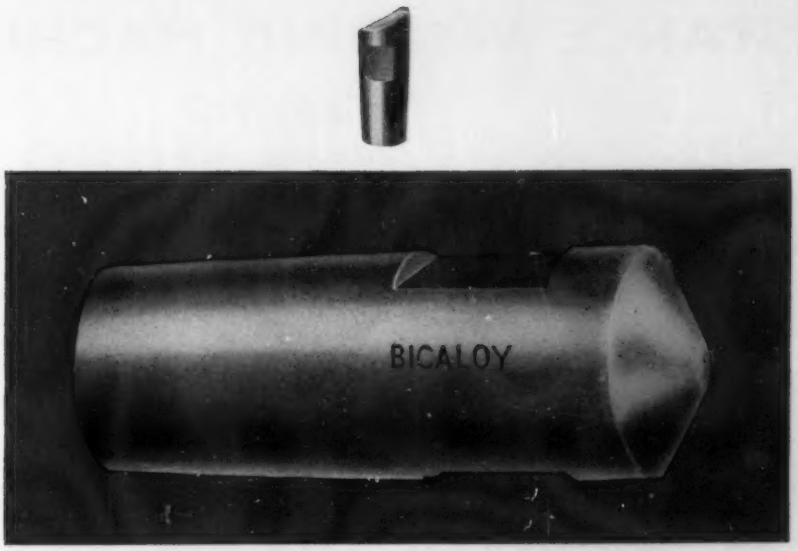

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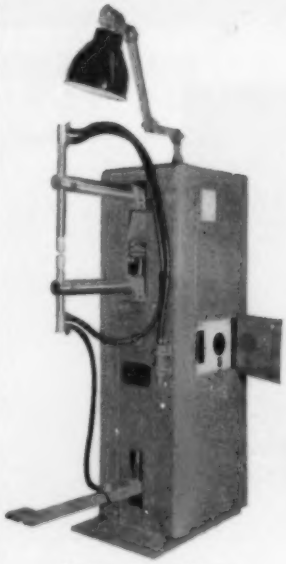

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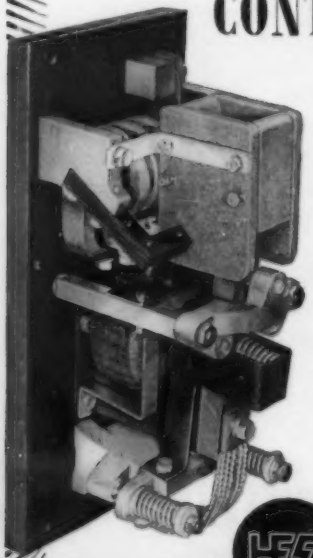

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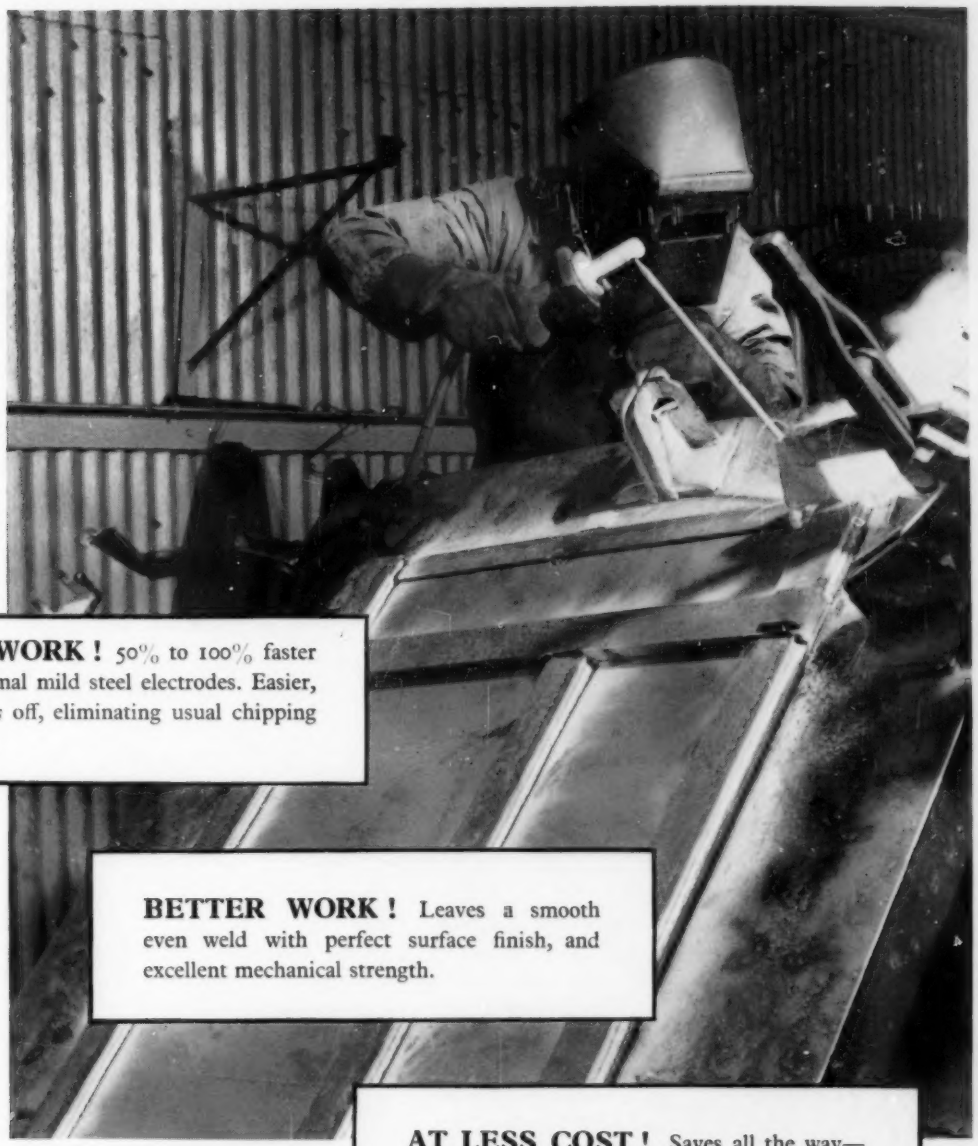

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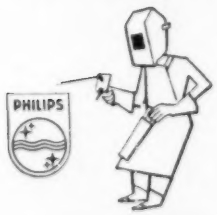

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